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THE LOOMIS COELOSTAT TELESCOPE OF THE YALE UNIVERSITY.

At our request Director Frank Schlesinger of the Yale University Observatory has kindly furnished us with the following brief description and accompanying photograph of the Loomis Coelostat Telescope. Those who attempt to do astronomical work in the cold winters of our latitude will appreciate how much this form of mounting a large telescope may add to the comfort of the observer. In spite of the distortion to which the large plane mirror is subject in rapid changes of temperature, there are several kinds of investigation in which valuable work may be done with the coelostat telescope.

The Loomis Coelostat Telescope is a memorial to Elias Loomis, for many years professor of natural philosophy and astronomy in Yale College. The optical parts were made by the Brashear Company, the mechanical chiefly by Warner and Swasey. It consists of a plane mirror thirty inches in diameter, mounted equatorially and driven by clockwork at the diurnal rate. This mirror can be pointed in every direction so as to throw a beam of light from any configuration upward through a long steel tube parallel to the Earth's axis. At the lower end of the tube are a fifteen-inch photographic objective and a ten-inch visual objective, both of fifty-foot focal length. They form images in a room at the top of a sixty-foot brick tower. This room can be heated, and the observer sits in a comfortable position, manipulating the telescope very much as though he were working with an ordinary microscope. Electrical appliances enable him to set the telescope on any object without leaving his chair, and a small telescope permits him to read the setting circles near the mirror sixty feet below.

The advantages of this form of telescope are its saving in cost (this being perhaps one-third of what a telescope of equal focal length would require if mounted in the ordinary way), and the convenience of the observer. Its disadvantage, which applies as well to all other telescopes in which oblique reflections are used, is the presence of astigmatism when the temperature is changing rapidly.

The Loomis Telescope is at present being used for the photometry of variable stars by means of the measurement of the density of star images. For this purpose it proves to be efficient and accurate.

THE GFH.

By MARGARETTA PALMER.

To the astronomer there are various initials of deep import, as the PGC for Boss's catalogue, AGC for the Gesellschaft catalogues, and many others not so well known. To this number there have recently been added another set of initials which are destined to become leaders of their kind, GFH, *Geschichte des Fixsternhimmels.*

Nearly half a century ago, in 1878, Arthur Auwers, at the Leibnitz meeting of the Königliche Preussische Akademie d. Wissenschaften, delivered an address on the subject "Préceptes pour Avancer les Sciences." Explaining the purpose of the Academy in the mind of its founder, Leibnitz,—to make accessible to everyone in a concise form the scientific knowledge possessed by individuals—he applied this principle to astronomy. As that address was never published we are unacquainted with his complete plan for accomplishing this result. We do know that he advocated the preparation of a general catalogue of all stars previously observed but his plan was not accepted by astronomers. The Gesellschaft catalogues and, later, the *Carte du Ciel* rendered further great undertakings in the astronomical world at that time impossible.

Almost twenty years later, in 1897, this plan was recalled from oblivion by a letter to the Academy from Ristenpart, then at the Heidelberg Observatory, in which he set forth the evil state of affairs when each observer or computer must hunt up and reduce every star-place he uses. He said that at least the first part of this often fruitless task could be spared by a card catalogue based upon the BD and Gould's DM with full references to all other sources where each star was found. From this card catalogue one could print a general index but it would have the serious objection that, as soon as it was printed, it would cease to be up-to-date. On this account it would be better to give the cards to some Bureau that additions might be made as each new catalogue was issued.

In 1900, at the celebration of the two-hundredth anniversary of the founding of the Academy, Auwers, then at the height of his fame, recognized as the supreme authority in regard to star-positions, again delivered an address. This masterly exposition of the chaotic condition of the sidereal astronomy of position and the steps necessary to remedy the evil, is, fortunately, preserved for us in the *Sitzungsberichte* of the Academy.*

Ristenpart, with the advice and approval of Auwers, had quietly begun the work to test the practicability, and later received a grant from

* Sitzungsberichte d. K. Preussischen Akademie. 1900. p. 657.

the Academy. Now Auwers announced that plans for carrying out the undertaking were arranged. Only the approval and sustaining appropriations of the Academy were necessary. These were readily granted as a fitting commemoration of the anniversary. Ristenpart was appointed director under the supervision of a committee with Auwers at its head, which was responsible for the orderly and scholarly prosecution of the work.

The program consisted of four parts:

1. The collection and orderly arrangement of all positions of fixed stars derived from meridian observations, or their equivalents, during the period 1750 to 1900 and already in catalogue form.

2. The reduction of those positions to the equinox 1875.0 and to a common system.

3. The compilation of a *General Catalogue* for the equinox 1875.0, based on the material thus collected. This catalogue would contain the coördinates of each star with the quantities necessary to reduce to any other epoch, including the proper motion in all cases where it could be determined from such material.

4. The publication of all the determinations for each star reduced to 1875.0 and chronologically arranged, and of the *General Catalogue*.

The equinox 1875.0 was chosen because

1. It lies near the mean epoch of all the observations.
2. Numerous star-places were already referred to it.
3. The means for reducing to this epoch were at hand.

Otto Struve's precession constants were used.

It was estimated that there were 1,000,000 determinations of 250,000 stars to be collected from 300 different sources—an estimate which proved too conservative.

Each step in this program presented grave difficulties quite apart from the amount and cost of the labor. In the first place many valuable observations had never been reduced and the observatories where they had been made had not sufficient funds to undertake the reductions. This difficulty was partially overcome by assigning such reductions to different astronomers who volunteered for that work. Astronomers of all lands were the gainers, for soon valuable catalogues appeared in print, containing observations which, but for the great enterprise of the *Geschichte*, would have remained in their original unreduced form.

As Ristenpart was at the Heidelberg Observatory the Bureau was located there till 1901, when it was removed to Berlin. In 1908 Ristenpart resigned to become director of the observatory at Santiago de Chile, taking with him several members of his staff. With few assistants Auwers directed the work in person till 1913, when Dr. H. Paetsch was placed in charge, Auwers retaining his position as head till his death in 1915.

Auwers was succeeded by Hermann Struve. Even during the war the work continued, though under difficulties and sometimes but slowly. In August 1920, Struve died. For lack of money the last helper left June 30, 1920, and Dr. Paetsch was obliged to continue the work alone.

In 1909 the first fruits of the *Geschichte* appeared, the *Fehlerverzeichniss zu den Sterncatalogen des 18. und 19. Jahrhunderts* by Ristenpart. This volume, which is of the greatest value to one who uses star catalogues to any considerable extent, contains the title and a brief description of every catalogue known to the Bureau in 1909, together with valuable corrigenda for the various catalogues. When this *Fehlerverzeichniss* appeared, the work was being pushed and the committee expected to carry out the entire program as speedily as possible. Later, when progress was slow on account of lack of means, it was decided to make the results already completed accessible to those astronomers to whom they would be useful; if desired, to furnish a copy of the star positions, or, at least to grant a look at the card catalogue. This offer still remains open and will not be withdrawn except for urgent reason.

It became evident that in time of war and the economic decline connected therewith it would be quite impossible to adhere to the original plans for the completion of the undertaking and that under these circumstances the best way to fulfil the original intention would be to shorten the program and publish the results already secured, that they might be of service in further scientific work.

It was, therefore, decided:

1. To separate the publication of the northern stars from the southern and to begin the publication of the former immediately.

2. To unite the third and fourth parts of the original plan in such a manner that for each star the collected determinations reduced to 1875.0 should be published without deriving proper motions or preparing a *General Catalogue*.

These northern stars are about 170,000 in number, with 550,000 positions entered from 300 catalogues. The first hour of right ascension has recently been published in one volume of more than 200 pages and it is hoped that the remaining 23 hours can be finished in ten or twelve years, but with the extremely small means at command it seems doubtful.

In accordance with the program the GFH will contain the star-positions of all catalogues and lists of meridian observations of the eighteenth and nineteenth centuries, including all catalogues whose equinox is 1900.0 with observations begun prior to 1901. To this there are two notable exceptions: *Berlin C*, as an integral part of the Gesellschaft catalogues, is included, although its equinox is 1905.0 and the observations are subsequent to 1901. Every star in Auwer's *New*

Fundamental Catalogue is entirely omitted because a complete discussion had already been published and their inclusion would, therefore, be superfluous.

For each star there are given, in general, the BD number and magnitude; the positions from every catalogue in which that star is found reduced to 1875.0, together with the abbreviated name of the catalogue, current number, equinox of catalogue, epoch and number of observations; the precession and secular variation. The right ascensions and declinations have been corrected for all the errors hitherto discovered; in many cases new reductions were made. A key to the abbreviations follows the introduction. It is probable that these abbreviations for the names of star catalogues will be generally adopted. Their use instead of the full name together with the abbreviated names of the constellations recently adopted by the International Astronomical Union will save much labor.*

In examining a work so colossal one is at first overawed by the results. Then the question arises: "What is its value?" The GFH, when completed according to present plans, will give in a usable form, for all northern stars at least and within the assigned limits of epoch, every meridian observation ever printed and some still in manuscript. Instead of searching through hundreds of catalogues we use one; instead of discovering for each catalogue whether the positions are given for the epoch of observation or the epoch of the catalogue—a puzzling question in the case of some of the older catalogues—we know at once and in every case that they are for the given epoch of observation; instead of discovering accidental and typographical errors in the original, which must be verified by new reductions, we have the results of a critical examination and comparison of various observations. Used in connection with the *Fehlerverzeichniss*, whose pages will explain apparent discrepancies between the GFH positions and the original positions of the catalogues, should we chance to find such, the work of determining accurate proper motions and the resulting positions for any epoch will be greatly reduced, while the labor involved in finding an approximate proper motion is almost nil. An instance of apparent discrepancy occurs in the very first star, as all the positions of *Bonn* AGC given in the *Geschichte* have been reduced to single observer.

If it had been feasible to complete the enormous amount of labor involved in carrying out the original plan, involving as it did the critical treatment of so vast an array of material, the astronomer who needs a few accurate star-positions and the investigator who finds in the study of proper motion a clue to the structure of the universe, alike would have rejoiced. Perhaps the greatest lack we feel is that there is no intimation of the weights for the various positions, a lack

*An account of these abbreviations by Professor Henry Norris Russell is given in POPULAR ASTRONOMY, October, 1922.

which we must ourselves supply from various sources but which was inevitable without critical comparison.

In planning the work of the *Geschichte*, Auwers said that his aim was "out of a chaotic mass to build an orderly structure with each star in its appointed place as a foundation for the sidereal astronomy of the future." He saw the materials for that foundation brought together in an orderly manner but was not able to complete the structure. Yet, even in its incomplete state the *Geschichte* will ever remain a worthy monument to Ristenpart and Auwers.

The name first suggested by Ristenpart, *Thesaurus Positionum Stellarum Affixarum*, by its very language is a reminder of the eighteenth century when Bradley began accurate determinations of star-places. *Geschichte des Fixsternhimmels*, the title adopted, savors of the nineteenth century when sidereal astronomy was a matter of position only. It will be the work of the twentieth century, not only with telescope and camera but also with spectroscope, interferometer, and instruments of which we only dream, to write another chapter in the large *History of the Starry Heavens*.

A METEORIC SATELLITE.

By WILLIAM H. PICKERING.

In the August-September number of POPULAR ASTRONOMY, Mr. Worthington calls attention to the possibility of our discovering such a body revolving about the earth. Our ordinary meteors and swiftly moving fire balls are probably generally composed of iron, and are known to move in cometary orbits. As distinguished from them stony meteorites, and possibly a few iron ones, have been shown to move in orbits of small eccentricity, coinciding closely with that of the earth (POPULAR ASTRONOMY, 1910, **18**, 262).

Under these circumstances the earth would necessarily have captured some of them, and they would accordingly now be revolving around it like our moon, and practically be our satellites. There is of course nothing novel in this idea, but the point of interest in Mr. Worthington's article is, that he suggests that they might possibly be discovered. Thus he says that one revolving at a distance of 2.66 radii from the earth's center, and one foot in diameter, would appear to us of the 15th magnitude. Now of the four hundred or more stony meteorites in our cabinets quite a number are as large as that, and a few are of double that size.

The largest one known fell at Long Island, Kansas, but was unfortunately fractured by the fall, since it struck on a stony ledge. The weight of its various parts amounted to some 1400 pounds. The density of the stony meteorites is considerably greater than that of

our surface rocks, and is practically identical with that of the moon, 3.5. A cubic foot consequently weighs 220 pounds. The volume of this meteorite was therefore a little over 6 cubic feet. When in space it would have been fully 2 magnitudes brighter than one of the size imagined by Mr. Worthington. The iron meteorites are larger still, the four largest measuring each over ten feet in length.

Since then such bodies undoubtedly exist, and since even if one were detected by an astronomer, it might possibly be mistaken for an ordinary meteor, and the observation lost, it is clearly desirable that we should determine, *(a)* when and where we should look for them, *(b)* how such a body would appear when viewed under the most favorable circumstances, *(c)* how we could distinguish it from a common meteor, *(d)* with what instrument we should be most likely to detect it, and finally *(e)* what observations we should make of it in case it were detected.

Our highest auroras extend to a height of 175 miles, and we have no actual evidence of any atmosphere above that. The pressure there must be many times less than that where the highest meteors first become visible—about 120 miles. Let us assume that our meteorite is one foot in diameter, that it crosses our zenith at a distance of 200 miles, and that its albedo is the same as that of the moon. It would then be 19.9 magnitudes fainter than that body. The visual magnitude of the latter when full is —12.5 (H. A. **61**, 71), so the magnitude of the meteor in that case would be 7.4. Unfortunately however it would then be suffering a total eclipse in the shadow of the earth. Indeed it could never be seen in our zenith when the sun was more than 20° below the horizon. Soon after sunset it would appear of a phase a little past the quarter. On the quarter its magnitude would be 10.1, and this is practically the brightest that any meteoric satellite could appear under any circumstances, if only one foot in diameter. A 10-foot satellite would be of magnitude 5.1.

If it were moving in a circular orbit its speed would be 1°.4 per second, if in a long ellipse it would reach 2°.0. No allowance is here made for the rotation of the earth, but this would be a small correction in any case, depending on the direction of the motion of the satellite. This might be in any azimuth. These are maximum velocities,—the body might easily be moving much more slowly, so that by its velocity the satellite could at once be distinguished from any slowly moving meteor of the ordinary sort, unless the latter were near its radiant. In that case however, its path would be short, so unless the satellite were going into eclipse, there need in general be no confusion between them.

Now as to the means of observing such a body. Under any circumstances, unless very large and remote, the satellite would be moving too rapidly to leave a trail on a photographic plate. If of the assumed size, it would also be too faint to be detected visually with any instru-

ment having an aperture of less than three inches. In fact a 3 to 5-inch telescope furnished with a 3-inch comet seeking eye-piece would be the likeliest means of finding it. It is the opportunity of the amateur. One could hardly recommend an observer however to spend his time in such a search. There are nevertheless many variable star observers at the present time, furnished with instruments of these dimensions, and as one of them might possibly be lucky enough to see such a body, it will now be well to suggest how it should be observed.

All the known satellites, revolving near their primaries, move in practically circular orbits. If we assume that our satellite does the same, that will greatly simplify our problem. We shall then need only two positions, one at the beginning, and one at the end of the observed track. If we are observing some special object when the satellite appears, that will at once give us our first position. We must then follow it carefully with the telescope, not losing sight of it for a moment. *The instant that it passes out of the field of view we must stop the telescope.* That will give us our second position. A stop watch would undoubtedly be the best means of determining the time between the two observations, but we should not be likely to have one at hand. A loud ticking clock would be the next best. In default of these, if we start humming or softly whistling some well known, strongly accentuated, and lively air, such for instance as that from Fra Diavolo, and stop at the second observation, on repeating this before a clock we shall get a pretty accurate idea of the time that had elapsed.

If we can see the satellite disappear suddenly in the field of view by going into eclipse, a time observation will give us at once its distance from the center of the earth, which will make an excellent check on our other results. In such a case however we should be very careful to see that it disappeared instantaneously, like a star occulted by the moon, for any change in magnitude would indicate that the body was a common meteor near its radiant. We should of course in any event record the apparent magnitude, in order to obtain an indication of the real size of the object. We should also notice its color, and whether its appearance was dull or sparkling.

While it would be of undoubted interest to detect such a body, especially if it proved to be of considerable size, and rather remote, yet it would be extremely difficult to determine its orbit with sufficient accuracy to render it possible to find it again, on account of the swiftness of its motion, and the correspondingly short time during which it would be visible. Nevertheless such an observation, if made by a well known, conscientious, and reliable observer, would be well worth publication, in the hope that someone else might succeed in detecting the same body, or possibly another one moving in the same orbit. On February 9, 1913, forty to sixty brilliant fire balls, as observed in Canada and elsewhere, followed one another within the space of three minutes, all moving in practically the same track, and travelling nearly

one quarter way around the world. We hope to refer to them in more detail in a later communication.*

Mandeville, Jamaica, B. W. I.
September 2, 1922.

TWENTY-EIGHTH MEETING OF THE AMERICAN ASTRONOMICAL SOCIETY.

(Continued from page 25.)

ABSTRACTS OF PAPERS

THE PROBLEM OF THREE BODIES AND THE SPECTRUM OF NEUTRAL HELIUM.

By Ludwik Silberstein.

After some introductory remarks on the prohibitive nature of the problem afforded by the helium spectrum on the ordinary treatment, and therefore implying the unattainable solution of the three-bodies problem, the assumption is made that the two electrons revolving around the nucleus of a helium atom *do not appreciably perturb each other*. The resulting spectroscopic formula is a simple sum of two Balmerian ones. This formula turns out to cover more than eighty of the one hundred and odd observed spectrum lines of helium, in the majority of cases within a fraction of an angstrom unit. Details, with a complete numerical table, of which a part only was shown at the meeting, will be found in the *Astrophysical Journal* for September, 1922.

A POSSIBLE NEW METHOD OF STELLAR PHOTOMETRY.

By Ludwik Silberstein.

The formula based on the quantum theory of photographic exposure (Cf. *Philosophical Magazine*, **44**, 257 and 252, 1922), and satisfactorily verified by experiments at the Eastman Research Laboratory, becomes for weak exposures,

$$k = N a n$$

where a is the average rise (area) of the AgBr grains, N their number spread originally per unit area of the plate, and k the number of grains made developable by the impact of n light-quanta. The energy value of the total exposure is directly proportional to n, at constant wavelength.

Thus for two star images, to be distinguished by suffixes 1, 2, we have, using the same plate and a possibly uniform one,

$$\frac{k_1}{k_2} = \frac{n_1}{n_2}.$$

*The paper referred to was published in the December, 1922, number of Popular Astronomy. A second paper is published in this number.

Counting, therefore, on a photomicrogram of the exposed and developed plate, the numbers k_1, k_2 of blackened grains, it will be possible to determine the ratio of the efficient light energies received from the two stars. To make the counting of the grains feasible, only single-layer plates can be used, requiring comparatively long exposures. Yet the proposed method of stellar photometry may offer some advantages, as it implies the incident light-energy in a more direct and simpler way than that based on the use of the ordinary many-layered plates, which imply the "growth' 'of the image and a host of factors characteristic to each emulsion and the process of coating.

The proposed photometric method will be tested experimentally by laboratory as well as observatory work.

OBSERVATIONS OF TEMPORARY WHITE AREAS ON MARS.

By E. C. Slipher.

Aside from the seasonal white caps over the poles of Mars whitish areas of more transitory character have been observed in the tropics of the planet, at the Lowell Observatory, from time to time especially frequently during the oppositions of 1920 and 1922. These white areas, which temporarily cover portions of the surface of the planet, are doubtless significant of physical conditions there, as regards atmosphere, temperature, and the presence of water vapor.

Lantern slides made from direct photographs of the planet showed various examples of these phenomena, including the extraordinary one of July 9, 1922.

Photographs of April 12, 1920, longitude center 330°, showed vast bright areas on the morning and evening sides of the disk, especially over the Syrtis Major where earlier photographs showed the same regions normally dark under like diurnal conditions. Photographs of May 15, 1920, same longitude, showed the bright area of the Martian morning all but gone and that of the evening edge altered in size and brightness but still obvious.

Likewise photographs taken on April 23, 1920, longitude 240°, showed the Syrtis Major hidden during the Martian morning by a bright covering from which it emerged normally dark long before noon as was shown by photographs made a few hours later on the same night. On the other hand photographs of May 24-26, 1920, showed the Syrtis Major arriving at Martian noonday partly concealed by a bright covering in latitude 2° S. that almost completely disjoined it from the dark Mare above.

The most remarkable phenomenon of this class was the great white spot first seen and photographed on July 9, 1922, where on the the 8th and previously nothing unusual existed. It was situated over the dark region of the Margaritifer Sinus. Being sharply defined except at the

south and almost as brilliant as the south polar cap and distinctly brighter than the north cap, it stood out with striking conspicuousness as it extended from longitude 5° to 30° and from latitude 12° to 25° S., thus covering an area of 300,000 square miles. Photographs of the spot on July 10, 1922, compared with those taken on July 9, showed that it had changed position and form, and that it was fainter as a whole but embraced a larger area than on the first night. Its motion was toward the Aurora Sinus and the north. On the 10th it was more manifest by the dark surface of the planet it hid than by its intrinsic brightness although in places it was quite bright. Photographs of July 12 showed only a remnant of the spot lying on the coast-line far to the right of where it first appeared. However on this date the Deucalion, above and to the left of the Sabaeus Sinus, was widely suffused with a lighter tint than on other dates indicating an entirely new disturbance of similar nature.

A complete discussion of the phenomena described above cannot properly be given here but it may be stated that systematic observation shows that they are atmospheric, that they differ from other temporary spots such as the glistening white patches marginal to the disk in the higher latitudes thought to be frost patches, as well as the yellowish bright patches occasionally seen on the planet thought to be dust clouds, and moreover their appearance, history and, indeed, everything about them betokens moisture clouds in the atmosphere of Mars.

It seems noteworthy, too, that dark spots of a transitory nature have been observed here some of which have been suggestively associated in time and place with this class of white areas.

THE STAR FIELDS FOR THE 1923 AND 1925 TOTAL ECLIPSES OF THE SUN.

By Frederick Slocum.

Whatever the outcome of the observations to test the Einstein theory during the eclipse of September 20, 1922, it will undoubtedly be desirable to repeat the observations at several future eclipses.

The eclipse of September 10, 1923, will be favorably located for American observers and totality will last about 3½ minutes. The field of stars suitable for testing the Einstein theory is very poor. There are two stars brighter than magnitude 8.0, within a radius of about two degrees from the sun, and 40 stars between 8.0 and 9.0.

The eclipse of January 24, 1925 is of interest chiefly because the path of totality passes directly over several observatories, including the Vassar, Yale, Van Vleck and Nantucket observatories. The star field is better than that of the 1923 eclipse, there being eight stars brighter than magnitude 8.0 within two degrees of the sun. The low altitude, the short duration of totality, about 90 seconds, and the nor-

mal winter conditions of southern New England will render the eclipse unfavorable for testing the Einstein theory.

Data for these two eclipses, including diagrams of the star fields, probable position of the corona, B. D. numbers and magnitudes of the stars, their distances from the sun and theoretical displacement according to the Einstein theory will be published in the *Astronomical Journal*.

NOTES ON IONIZATION IN THE STARS.

By John Q. Stewart.

It is probable that the spectral characteristics, upon which the classification of the stars by spectral type depends, indicate (in a general way) the degree of ionization in the stellar atmosphere. If this is so, a given degree of ionization should be reached at a lower temperature in stars of low density than of high density, and giant stars should be redder than dwarf stars of the same spectral type—as Seares has found to be the case.

Assuming that the effective average ionization potential which determines the classification is about six volts, and taking temperatures from Seares' data, the ratios of the pressures in the atmospheres of giant and dwarf stars of types F to K come out in close agreement with the ratios of surface gravity in the corresponding stars, calculated from the best available data.

For elements of easier ionization than the average, the enhanced lines should be stronger in giants than in dwarfs of the same spectral class, and the arc lines stronger in the dwarfs. For elements harder to ionize than the average, the reverse should be the case. The first of these propositions explains the importance of the enhanced lines of strontium in the giant stars.

Any chemical or physical change which results in an increase of the total volume of the gas will be favored in stars of low density (for the same temperature). If the chemical equilibrium which appears to exist between the compounds which produce the characteristic bands in Classes M and N is such that the N type of spectrum corresponds to the greater volume, the presence of this spectrum only in giant stars of great luminosity and very low density may be explained. This hypothesis is supplementary to that of differences in relative abundance of the reacting substances, advanced by Curtiss and Rufus, rather than alternative to it.

CHRONOGRAPHIC RECORDING OF WIRELESS TIME SIGNALS.

By R. Meldrum Stewart and J. P. Henderson.

In a communication to the meeting of the Society in 1920 it was shown that in the chronographic recording of wireless time signals by the method of inserting a sensitive relay in the plate circuit of an amplifying valve, there are systematic differences of the order of .01 sec. and larger, depending, among other causes, on the method of introduction of the local clock-beats and on the strength of the wireless and clock signals. Presumably these differences are due to variations in the lag of the relay or chronograph, probably induced by hysteresis or allied effects.

Further experiments, involving measurement of the actual relay lags involved, have shown that by introducing clock signals in a suitable way, by the use of suitable condensers ,and by exercising sufficient care in perfecting the adjustments, these systematic errors may be practically eliminated. In actual practise, however, these conditions are not likely to be always fulfilled, and the method is therefore open to serious objection.

It has, however, been found possible to perfect a relay arrangement in which there is reasonable assurance that the lag for signals of any kind will be the same, within limits of the order of .001 sec.; it is thus possible to introduce the clock signals by any convenient method; the adjustments required are simply those necessary to make the signals carry through the relays.

The arrangement comprises two relays, the first consisting of a telephone receiver with a tungsten contact mounted on the diaphragm, as described in the previous communication, the second an ordinary telegraph relay. By a suitable cross-connection of coils and points of these relays it is possible to ensure the carrying through with a constant lag of any signal which will operate the telephone relay, the reaction time of which is of the order of .001 sec. This is effected by putting the coils and points of the telephone relay in series, so that when once opened it will remain open, the circuit being restored by the second relay only after the latter has opened to its fullest extent.

During February and March of this year chronographic records of signals were made on forty occasions, the same set of signals being in every case received also with the telephones by the method of coincidences by extinction. The mean systematic difference between the two methods was .002 sec. $\pm$ .001 sec. Treating the differences as accidental the probable error of an individual difference was $\pm$ .005 sec.; as the two methods were entirely independent it appears to follow that the probable error of reception of a single set of signals by either method is less than this quantity.

A more detailed description and discussion will be given in a forthcoming publication of the Dominion Observatory.

ON THE SPECTROSCOPIC BINARY 13 γ URSAE MINORIS.

By Otto Struve.

This star (α 15^h 21^m, δ +72° 11′, 1900, magnitude 3.14, spectrum A2) was first suspected to be a spectroscopic binary by Messrs. Barrett and Lee. On February 13, 1922, six exposures were made on this star, the measures of which proved the variability in radial velocity with a very short period. Between February and August 200 spectrograms were secured, most of them with the dispersion of one prism and only a few with the three-prism arrangement. All the observations between February and August can be combined by a period of 2^h 36^m 10^s, but the shape and range of the velocity curve seem to vary considerably, not only from one night to another, but even during the same night. The range of the mean velocity-curve is therefore somewhat smaller than the actual range of the individual curves. The following elements for the orbit were obtained by Lehmann-Filhés method:

	Mean	λ4481
V =	−2 km	+3 km
P =	0^d.108449 = 2^h 36^m 10^s	0^d.108449
e =	0.09	0.11
K =	14 km	18.5 km
ω =	160° 2′	161° 1′
T =	1922 May 29, 17^h 30^m	17^h 31^m
$a \sin i$ =	35000 km	50000 km

The line λ4481 seems to have a larger range than the other lines (titanium, iron) and the elements were obtained for the mean of all the lines and for λ4481 separately.

It is of interest to note, that γ Ursae Minoris has been found by Guthnick at the Berlin-Babelsberg observatory to vary in brightness with a very small amplitude, of the order of 0.04 magnitude. At the request of Prof. E. B. Frost the photometric observations were repeated last May at Babelsberg by Dr. Bottlinger. The former results were confirmed, the variations occurring in very short intervals of time (2-3 hours) but no definite period could be established. Sometimes it seems that the photometric observations could very well be explained by a period of about 2.5 hours, but the spectroscopic period does not combine the photometric observations of different dates.

I am continuing the spectrographic observations of this star at the Yerkes Observatory.

The dimensions of the spectrographic orbit are much smaller than could be expected for a real double star. (The same is true for all other spectroscopic binaries having very short periods.) From a curve combining absolute magnitude and the width of certain lines for stars of sp.-type A2-A5 the absolute magnitude of this star was found to be +1.6. From Adams and Joy's new curve its absolute magnitude would be +1.5. Russell's table gives for the linear diameter of such

a star twice the diameter of the sun. The center of gravity of the system is therefore inside the brighter body. If the satellite is revolving at a reasonable distance from the main body, we would find for the satellite a linear velocity that can hardly be expected for any star (a range of about 400 km/sec. at the surface of the higher component).

If we suppose our star to be a pear-shaped body with two very pronounced nuclei, we find for the density $\rho > 3$ (sun).

The pulsation theory gives for the density a more reasonable value $\rho = 0.5$. But there are some other contradictions between the theory and the observed facts. The spectral lines should be broadened at maximum and minimum of the velocity curve, and this broadening, as can be shown easily by computation, should be very pronounced. No trace of such a broadening can be found on our plates. On the contrary, it seems that a slight broadening exists at the points of γ-velocity. On the other hand, supposing the diameter of the star to be twice that of the sun and its density 0.5 that of the sun, we can compute the variation in temperature and the ratio of radiation due to the process of oscillating. The variation in temperature derived by this method appears to be many times 10,000° C., which is of course impossible. If we should start from the observed range in light variation, we could explain the observed range in radial velocity only under the assumption, that the diameter of γ Ursae Minoris is 7 times the diameter of the sun. Then, since $\rho = 0.5$, we would have a value for the mass ,that exceeds by many times that of the sun, and this is not very probable.

COMPARISON BETWEEN PARIS AND WASHINGTON TIME SERVICES BASED ON CHRONOGRAPHIC REGISTRATION OF BORDEAUX, ANNAPOLIS, AND ARLINGTON RADIO TIME SIGNALS.

By Frank D. Urie.

During the favorable radio season, November, 1921 to March, 1922, thirty-five satisfactory chronograph records of the Bordeaux rythmic time signals were obtained at Elgin, Illinois, using a single wire aerial 180 feet long and 30 feet high in connection with the radio recording apparatus described by the writer at the 26th meeting (*Publications of the American Astronomical Society*, **4**, 289, 1921.) On each of these days records of the Annapolis or Arlington time signals were also obtained. On all records the beats of the mean-time clock, Riefler No. 224 of the Elgin Observatory, were recorded on the chronograph sheet by the same pen that recorded the radio signals.

Thus the data were at hand for an accurate comparison between and Washington time services. Corrections to the observed differences were made for (a) the lag of Annapolis or Arlington, (b) the

error of the Washington time signal, both furnished by the Naval Observatory, (c) the correction to the Bordeaux signal, furnished by the B. I. H., Paris Observatory, (d) transmission time of Bordeaux, 0.02 sec., and (e) change in correction of Riefler No. 224 during the three hours between signals.

The following table gives the final values for the difference between the Paris and Washington values of No. 224 correction.

1921 Nov. 15	+0^{s}10	1922 Jan. 13	—0^{s}07	1922 Feb. 2	+0^{s}10
Dec. 13	+ .01	16	+ .06	3	+ .10
15	+ .05	18	— .01	6	+ .10
19	— .05	19	— .06	7	— .04
30	+ .03	20	— .08	9	+ .06
1922 Jan. 3	— .01	23	+ .09	10	+ .08
4	.00	25	+ .05	13	+ .06
5	+ .03	26	+ .02	14	+ .05
6	— .02	27	+ .02	15	.00
9	+ .03	30	+ .15	16	+ .11
11	— .03	31	+ .03	Mar. 3	+ .13
12	+ .03	Feb. 1	.00		

The mean value is +0^s.032 ± 0^s.007, the sign indicating that the Washington values of No. 224 correction are larger than the corresponding Paris values.

OBSERVATIONS OF JUPITER'S FAINT SATELLITES AND OF PHOEBE, WITH THE 2-FOOT REFLECTOR OF THE YERKES OBSERVATORY.

By G. Van Biesbroeck.

Pairs of plates of the field of these faint objects were taken with a moving guiding eye-piece, so as to compensate for the motion of the object. The stars appear slightly trailed but measurable round images of the satellites are thus obtained in relatively short exposures. The satellites were located on the plates by means of the blink-comparator. The positions were obtained by referring the satellite in x and y to three nearby faint comparison stars and the positions of these in turn were obtained from astrographic plates taken at the Uccle Observatory through the kindness of M. Lecointe.

Jupiter VI, VII and VIII were photographed on 5, 4 and 5 nights respectively and the corresponding numbers of plates are 7, 6 and 10 respectively. Besides 5 plates of Phoebe were obtained on 3 different nights. Mr. O. Struve joined in taking the exposures. The details of the measures will be published elsewhere. For Jupiter VI, Jupiter VII and Phoebe the observations are represented without any great errors by the positions given in the *American Ephemeris* and computed from F. Ross's elements.

RADIAL VELOCITY OF THE PRAESEPE CLUSTER FROM OBJECTIVE-PRISM NEODYMIUM PLATES.

By H. C. Wilson.

Measures of spectra of thirteen of the brighter stars in the Praesepe cluster, photographed through a solution of neodymium chloride with the 16-inch Metcalf Telescope and objective prism of Harvard College Observatory, give an average radial velocity with reference to the sun of about 0 km/sec. The uncertainty is perhaps ±10 km/sec. For individual stars on the best plate the velocity ranges from +77 to —65 km/sec. The large part of this range is probably due to accidental errors of measurement, owing to the very small scale of the spectra. The fainter stars give a larger range, but very nearly the same average.

The poorer plates cannot be trusted at all on account of the uncertain effect of definition on the single neodymium reference line.

Measures of similar spectra of six of the bright stars of the Pleiades on one plate gave for the average radial velocity +6 km/sec. while the mean of the Yerkes results for the same stars is +9 km/sec.

ECLIPSING VARIABLES SHOWING TWO SPECTRA.

By Charles Clayton Wylie.

Elements and absolute dimensions are now available for fifteen eclipsing variables showing two spectra:

σ Aquilae	RX Herculis	U Ophiuchi
β Aurigae	TX Herculis	V Puppis
TV Cassiopeiae	u Herculis	W Ursae Majoris
U Coronae	Z Herculis	RS Vulpeculae
Y Cygni	β Lyrae	Z Vulpeculae

The elements of σ Aquilae, which is included in the above list, have recently been determined from a light-curve based on photo-electric observations made at the University of Illinois.

Provisional elements have been published for two other stars of this class, S Antliae, and RS Canum Venaticorum.

Joy's provisional spectroscopic elements place WW Aurigae, Boss 1646, in this class, and show that the period in Hartwig's 1921 catalog should be doubled. This star is now being observed at the University of Illinois, and preliminary results for the light-curve are

	M
Maximum	5.98
Primary minimum	6.73
Secondary minimumu	6.54

Combining with Joy's spectroscopic results we have

Radius relative orbit	12.5 radius of sun
Radius of each star	1.9 " " "
Mass of primary	2.2 mass of sun
Mass of secondary	1.9 " " "

According to Miss Maury μ^1 Scorpii is an eclipsing binary of this class, but no light-curve is as yet available.

PROPER MOTIONS OF SOME FAINT STARS.

By Everett I. Yowell.

Several catalogs of the proper motions of faint stars, obtained by micrometric measures have been published, notably those of Otto Struve, Comstock, and Burnham. Examination of photographic plates has led to the publication of lists by Wolf, Innes, Turner and other Oxford observers. Such stars as have an indicated motion of over 20″ a century have been put on the Cincinnati lists for further investigation. A table of some of the results obtained was given, showing general agreement with the provisional values, but with many discordances.

UNIFORM CLOCK RATES FOR A PERIOD OF AN ENTIRE YEAR.

By M. L. Zimmer.

The first series of fundamental observations, made after coming to Cordoba early in 1913, pointed unmistakably to the fact that clock corrections obtained in the evening were larger than the corresponding ones obtained in the morning. The investigation of the cause of this, requiring as it does that the clocks be kept under strictly uniform conditions of temperature and pressure, led to the early construction of the new subterranean clock room (*Astronomical Journal*, No. 762).

In the article cited, it was stated that clocks running undisturbed under such conditions would give uniform rates for the entire year, and this expectation has been fulfilled. The two Riefler clocks Nos. 155, and 330 were installed in this room in the early part of 1919, the pendulum of Riefler No. 330 swinging in the meridian and that of No. 155 at right angles to it. Owing to several tests and experiments the room was not ready to be permanently closed until the following September, and from that time until about the end of October of the following year the clocks ran without any known disturbance, no one having even entered the room during that time; but from this date, for several months, the clocks were rather frequently disturbed by earthquakes.

During this period about 15,000 observations were made for the further investigation of the night and morning phenomenon as well as to furnish the basis for the reduction of our fundamental observations of the full list of Boss' 1059 stars south of $+30°$. Also during that same period Senor Chaudet took time sets at more or less regular

intervals for assuring exactness in the signals of the Argentine time service. No attempt was made to obtain an exceptionally high order of precision in these clock corrections.

A study of the graph together with a few trial tests showed that they would be represented by the following formula:

$$-16^s.495 - 0^s.0811\,t + 0^s.0001902\,t^2 + 0^s.3172 \sin 2\odot - 0^s.2303 \cos 2\odot + 0^s.0205 \sin 5\odot + 0^s.0567 \cos 5\odot = \Delta t.$$

where Δt = clock correction, t = number of days from February 29, and $\odot$ = true longitude of sun for date of observation.

With this formula clock corrections were then computed for the dates of observation and the column headed O — C shows how well the formula represents them.

		O — C			O — C
1919 Oct.	1	+0s.04	1920 April	15	—0s.01
	16	.00	May	4	— .01
	27	— .07		31	+ .03
Nov.	10	+ .01	June	30	+ .01
	19	+ .03	July	13	+ .01
	23	+ .05	Aug.	6	+ .01
Dec.	14	— .04		23	+ .07
1920 Jan.	8	— .08	Sept.	8	— .02
	26	— .01		25	— .05
Feb.	11	— .02	Oct	5	+ .01
Mar.	3	+ .03		8	+ .06
	25	+ .01		14	+ .03

p. e. ±0s.024

Smooth curves were computed, the first from that part of the rate depending upon t, t^2, and $2\odot$, while the second curve was computed from that part of the rate depending upon $5\odot$.

The preliminary investigation of the more complete program made by Senor Guérin, which has about 400 conditional equations, shows that there are several curves of still shorter period superimposed on those two. Of course the effect of the change in longitude, produced by the latitude variations must be present. The complete formula, when the periodic and casual error of star places have been eliminated, will represent the observations with a probable error of less than half of that shown above. There can be no doubt about the reality of the first curve. Several causes have suggested themselves, but no attempt at an explanation is made at this time. Since both clocks traced out this same curve during the period, and from the fact that we have had glimpses of it from shorter periods of uninterrupted clock rates, we have every reason to suppose that it will be repeated in subsequent years. Should such be the case it will require explanation. The clocks have now been running under uninterrupted conditions since January 25th of the present year and, should we be fortunate enough to finish out the year without interruption, we should be in possession of data to settle this point.

The results need no comment, they speak for themselves. The test has been a severe one but the clocks have measured up to it in no uncertain way. I need hardly point out the value of such uniform rates. The value to fundamental work will be seen at a glance, since with such rates whole years observations may be reduced in the same manner as those of a single night. Neither do I need to point out what new fields will be opened up for the study of gravitational problems and the possibilities of new discoveries.

THE METEORIC PROCESSION OF FEBRUARY 9, 1913.

By WILLIAM H. PICKERING.

PART II.

In our former paper on this subject we derived the numerical results on which the conclusions to be arrived at in the present paper are based. On referring to Professor Chant's original article (Journ. R. A. S. Canada, 1913, **7**, 145), we find reports from 141 stations, the positions of most of which are indicated on the two maps which accompany it. The most remote station from which the meteors were seen was Winchester, Ontario, 230 miles distant, to the north of the track. The next most remote in Canada was Sturgeon Falls, 180 miles, also to the north. The most remote station to the south was Marshall, in southern Michigan, 210 miles. The meteors were thus visible under favorable circumstances throughout a belt some 450 miles in width.

The sound produced by their rush through the air, which was described as resembling thunder, or distant cannonading, was heard at Edgar 78 miles to the north. The next most remote station was at Unionville 50 miles distant. The most remote to the south was Cayuga at a distance of 20 miles. There were many scattered stations to the north more remote than this. No sound was heard at Bermuda, distant 57 miles, nor on the ships at sea. The Newlands was only 35 miles distant, and the meteors at a height of 14 miles.

At eight stations a trembling of the house or ground was felt. All of these stations were located to the north of the track of the meteors; at Rothsay the distance was only 2 miles, at the others 20 to 40; most of them were distant about 35 miles (see map Figure 1). The towns are indicated by their initials, and named in order are Rothsay, Keldon, Shelburne, Caledon East, Sand Hill, Toronto, Wexford, and Niagara-on-Lake. There were several towns within only 10 miles of the meteor track where the observers reported loud sounds, but failed to notice the trembling. Such are Waterloo, Berlin, Guelph, Hespeler,

Fonthill and Ridgeway. It is curious that these near towns were apparently unaffected.

When we consider the small mass of the meteors, which were only a few feet in diameter, and the comparatively small amount of energy that they lost per mile in their course, it certainly seems surprising that through such a wasteful mode of transmission as an air wave, such a tremendous volume of material as the surface of the earth could be shaken. It illustrates clearly how sensitive we are to very slight vibrations. Thus at Wexford, some forty miles from the track, the observer says "We all heard the thunder; it fairly made the house shake, and we said there was another earthquake in Toronto." Since the sound was not as loud as a heavy thunder clap, we may wonder

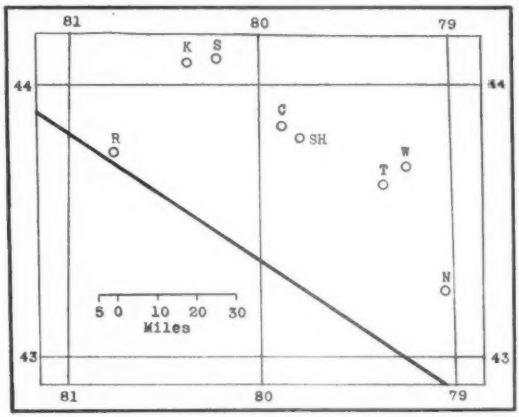

FIG. 1.

why the ground was shaken at all. An obvious difference between the two lies in their distance from us. From a height of 35 miles all the ground of a district would be reached at the same phase of the vibration, and shaken simultaneously, while in the case of a thunder clap the disturbance would reach different regions successively.

It may be suggested that perhaps the ground was not shaken at all, but only the houses, and in this case we can understand that houses 35 miles distant, whose roofs lay perpendicular to the direction of the sound waves, might be more shaken horizontally than those houses that lay directly under the track of the meteors. Most of the observers who noted the vibration either state that they were in the house, or imply as much. Thus the Rothsay observer, who was located near the track, did not see the meteors at all, so presumably was in the house. On the other hand, of the seven other observers, the one at Caledon East gives a brief description of what he saw, and then adds "there was a noise like a short crash of thunder, and I imagined that the

ground shook under me." The observer at Sand Hill, near Caledon, describes the display in full, and then says "there was a loud report like rolling thunder, and then another sound like thunder, and a tremor of the earth. These last two statements certainly sound as if the observers were out of doors. If so, and the whole surface of the earth shook, we can only suggest that for distant observers a horizontal or inclined vibration was more noticeable than a vertical one would have been to those who were nearer at hand. In any case the wonder of the shake remains, although the observation is by no means novel. We wish we could have learned if the sound or the shake was perceived by any of the innumerable observers who must have witnessed the display in the United States, but whose observations unfortunately are now unrecorded and lost.

Only about ten per cent of the observers timed the meteors. Fortunately there were so many records in Canada that all the important phases of the display were noted. By Table 1 we find that the beginning occurred at $9^h\ 05^m.5$, and the end at $9^h\ 12^m.5$. It is probable that the observers of the end waited a little to see if there were any more meteors to follow. The first two looked at clocks, and very likely had to walk some little distance to see them, so we shall perhaps be safe to call the time of the end of the display according to these observations $9^h\ 11^m.5$, and its duration 6 minutes. Four observers failed to say what it was that they observed, but merely said "time $9^h\ 10^m$" or whatever the figure might be. Perhaps it was the middle of the display, since their average comes 3 minutes after the beginning. Many observers estimated the duration, but only two, at Hespeler and at Toronto, timed it directly. Their results are $3^m\ 40^s$ and $5^m\ 40^s$. Apparently both saw the whole of the display. The estimates run all the way from 1.5 to 8 minutes.

TABLE I.

TIME OF THE DISPLAY.

Beginning		Time		End.	
Location	E. S.T.	Location	E. S.T.	Location	E. S.T.
	h m		h m		h m
Bolton	9 05	Caledon East	9 07.5	Centreton	9 15
Jarvis	07.5	Coldwater	08	Milliken	12
Springbrooke	06	Toronto	10	Parry Sound	10
Springville	04.5	Unionville	10		
Toronto	05				
Means	9 05.5		9 08.5		9 12.5

The average was 3.3 minutes, but as some observers saw only a portion of the procession, and as all such estimates are likely to be too short rather than too long, it would seem safe to call the duration from 5 to 6 minutes, which is perhaps as close as it is possible to estimate such an indefinite event as the end of the shower.

Four observers recorded the time when they heard the sound of

the meteors, and a fifth recorded the interval that had elapsed from the passage of the first meteor until he heard the sound. One of the former said that his time was only approximate, and as it was manifestly wrong, we will consider only the observations of the other four. One of these was from Hespeler and one from Fonthill, both being directly under the track of the meteors. The two others were in Toronto. The meteors came in successive groups, the first ones being the brightest. The sound came in successive crashes, the first ones being the loudest. It is therefore manifest that the first crash was produced by the first group as they passed. As the meteors rush through the air, small pieces are constantly broken off from them, and they sometimes break in two, but these fractures probably produce but little noise. The roar and crash heard is, like that of a thunder clap, due to the sudden heating and displacement of the air as the meteor passes.

Since the velocity of the meteors was more than twenty times that of a sound wave, the first sound to reach an observer came from that portion of the path which was nearest him. The distance of the meteors above Hespeler and Fonthill was 35 miles, their direct distance from Toronto 49. The sound reached the Fonthill observer at about $9^h\ 10^m$. The two observers at Toronto agreed that it arrived at $9^h\ 12^m$. The Hespeler observer states that the interval after the first meteors was 4 minutes and 30 seconds. Taking the passage of the first meteors at $9^h\ 05^m.5$, this gives the same time as for the Fonthill observer. Reducing the intervals and distances to seconds and feet, we find the velocity for Hespeler and Fonthill was 684 feet per second, and for Toronto 663; mean of the four observations 674.

On July 27, 1894, an accurately observed meteor was recorded at the Lick Observatory, and it was concluded that the velocity of the accompanying sound was transmitted at a speed of 800 feet per second. The velocity of sound is dependent on the temperature of the air, but independent of the pressure. The air being colder in February, we should naturally expect the velocity to be somewhat lower, though not as much so as shown. Given the velocity of the sound, it is a simple matter to compute the mean temperature of the air, since the velocity $v = 1086\sqrt{1 + 0.003665\,t}$, where t is the temperature in degrees Centigrade.

According to the Lick observation it appears that the temperature was —125° C., according to the present investigation —169° C. These temperatures are far lower than anything that has been obtained by balloons in the isothermal layer. At an altitude of 8 miles in the latitude of Toronto we might in the winter time expect to find a temperature of —60°, and that the temperature would not vary very materially up to 13 miles, which is at about the limit at which measurements have been made. There is no reason to suppose that the tem-

perature would fall off greatly for the next 20 miles above that. These meteoric results therefore are most unexpected.

Other Canadian observers give confirmatory results, but they are not sufficiently definite to be useful. . Several for instance state that the sound was heard so many minutes after the meteors had passed, but do not state at what time they consider that event to have occurred, nor how long it was since the passage of the first meteors. While the velocity of sound is independent of the density of a given transmitting medium, it may be that when progressing from a rarer to a denser portion its velocity is diminished. I do not find that this question has been considered previously. Accepting the observations as correct, there seems to be no other obvious explanation for the very low speeds found both in California and Ontario. As shown in my first paper, the height in Ontario cannot well have been much over 35 miles. To check the matter further, however, let us assume that the mean temperature of the atmosphere between the meteors and the four observers was —60° C., —a not improbable figure. At this temperature the velocity of sound is 959 feet per second. The corresponding distances from Fonthill and from Toronto would therefore be 49.05 and 70.85 miles respectively. The height of the meteors would then be 44.88 miles, and the track would lie 19.80 miles to the southwest of Fonthill. While a height of 44.88 miles, leaving out all other considerations, is not improbable of itself, yet a distance for the track of 19.80 miles southwest of Fonthill, is absolutely out of the question. If we accept the Fonthill and Hespeler observations alone as above given, and the correct location of the track, the height of the meteors comes out 49.05 miles. If we accept the two Toronto observations, and reject those at Fonthill, the height appears to be 61.60 miles. This deviation is clearly unsatisfactory, and since all four observations agree when we adopt the accepted location of the track, and a velocity of 670 feet per second, we thus by this means secure an independent check on the height, as being in Ontario very close upon 35 miles.

Showers of meteorites when found on the earth are usually all of one kind, either all of iron, or all of stone. Showers of the former, like those of Meteor Crater and Toluca are rare, and it is believed that in those cases the individuals may have been travelling separately in space before they reached the earth's atmosphere. At all events they could hardly have broken up until they were intensely hot. When sufficiently heated however, iron meteorites like that of Hraschina, have actually been seen to break in two. Stony meteorites on the other hand frequently come in showers, and it is believed might fracture even at a red heat. A few meteorites like those of Estherville and Crab Orchard are made up in part of both iron and stone. A very interesting feature of the descriptions of the procession of 1913 is that some of the meteors exhibited different characteristics from some of the others. This fact was noticed by over a dozen different observers.

At first the meteors came in separate groups. At the more western stations all the individuals appeared alike as to color, and different only in size. One of the best accounts is from the town of Jackson, which lies about 40 miles to the north of the track. By the word "head" the observer apparently means the head of the column, that is to say the first group of meteors. "It was a cold, calm, starlight night. Suddenly, from the northwestern sky there appeared what looked like an immense ball of red fire coming towards us at a tremendous rate with a long tail streaming behind it..... The head seemed much larger than the full moon, very red, and the tails extended a considerable distance behind, with pieces of the tails dropping off from the head every little while. ..... In a minute or two we saw some smaller ones in the same track."

Only a few miles farther along the course a new phenomenon appeared. The correspondent at Appin, 80 miles to the south, sends in the following report. He begins "A huge meteor appeared travelling from northwest by west to southeast, which, as it approached, was seen to be in two parts, and looked like two bars of flaming material, one following the other. They were throwing out a constant stream of sparks, and after they had passed they shot out balls of fire straight ahead that travelled more rapidly than the main bodies. They" (that is the group of meteors), "seemed to pass over slowly, and were in sight about five minutes. Immediately after their disappearance in the southeast a ball of clear fire that looked like a big star, passed across the sky in their wake. This ball did not have a tail or show sparks of any kind. Instead of being yellow like the meteors, it was clear like a star." Several observers commented on its whiteness as compared to the other meteors and, like the observers at Parry Sound and at Rodney, placed it at the end of the procession.

None of the seven earlier observers to the west of Lake Huron noticed it, although several of them commented on the size and brightness of the leaders. The three most western stations from which it was seen were Thamesville, Appin and Rodney. The observer at the first of these stations states that the meteors came in perhaps a dozen groups, and gives a sketch of their appearance. She then adds "One big body floated along by himself after about the fourth group." She shows it without a tail, but the observer at Rodney, unlike the others, says it had a long tail. In this he was probably mistaken. Discrepancies of this sort are not unusual. Thus the observer at Magnetawan agrees with the others that it was tailless, but adds that when it was "about midway from horizon to horizon it burst, and sent forth a shower of sparks, much like a rocket, and for a second it brightened the sky." It seems odd that the other observers did not notice this. All of them saw the meteor in about the same portion of its path. Probably the Magnetawan observer confused it with some other meteor in the procession that did burst.

An observer at Caledon East, who saw it some fifty miles further along than the one from Magnetawan, says "About three-quarters to the end there was a big star with no tail, alone, with a few following." The observer at Fenelon Falls who saw it still later, after describing the procession of meteors, adds, "The whole was wonderful, but the most wonderful was the lone star following the first cluster." This statement would seem to imply that the procession of yellow stars with their tails was gradually falling behind, and not keeping up with the lone white star. However, one of the Toronto observers says "About half of them had passed when an unusually large one hove in sight, fully ten times as large as the others." The earlier observers we notice placed it at the end of the procession or following it, while one a little later said it was three-quarters way from the front.

Information from the United States as to its location, and as to what happened next would be of much interest, for when the meteors reached Bermuda we find that the white star had broken in two, and now led the procession. The observer writes, "The two leading bodies like large arc lights in appearance, slightly violet in color," etc. These were followed closely by yellow, and later by red smaller bodies. Both of these leaders were now breaking into smaller pieces. "As these pieces separated from the parent bodies they developed trails of sparks and gas." Another observer also saw the two leaders, and states that later one of them "burst all to pieces when well away from the land." The last observer to see the shower was on the ship "Newlands" 3,000 miles from Bermuda. He records that he was just about to leave the deck when his "eye was caught by a bright shooting star in the western sky that travelled way across the heavens." He adds "I had just time to yell out to the second mate, who had relieved me on the bridge, when a whole shower of stars of the same kind came shooting across in the wake of the first one." It thus appears that the bright star that we have been describing had now got well ahead of all the others.

To explain these observations we note that at Mortlach, where first seen, the meteors were at a height of 50 miles. Before that, and since passing near Edmonton, they had been traversing an almost uninhabited district, and steadily approaching the earth. They were therefore just beginning to get hot enough to be rendered visible. The widely separated groups, which were from sixty to one hundred and fifty miles apart, were all travelling at the same speed, and were therefore distinct bodies before reaching our atmosphere. From the ease with which they broke up, and formed tails so early in their career, while only red hot, we conclude that they must in general have been stony meteors.

At the end of the procession however, and moving in the same orbit as the others, was what seems to have been an iron meteor. Owing to its ready conductivity its surface did not heat as quickly as that of

the stony ones, and so did not become conspicuous until it had reached Ontario. Neither did it throw off slivers to form a tail until it was much whiter and hotter. This was the case in Bermuda. Owing to its greater mass in proportion to its surface, it suffered less relative resistance from the air, and so while starting near the end of the procession, it at length took its position at the head, where it got white hot, and became so heated through and through, that it broke in two before reaching Bermuda. Finally only one of these parts survived to be seen from the steamer Newlands.

The composite character of this stream therefore gives us a clue by which we may decide on the composition of those fireballs which are not known to reach the earth's surface. Most of them belong to the swiftly moving variety, and are therefore composed of iron. Unless their real motion is very swift indeed, or exceptionally long enduring as in the present case, they do not have tails. The rarely seen, slowly moving kind, are composed of stone as a usual thing. These sometimes have conspicuous tails, and are the ones which are most likely to reach the ground. The length of the longest tails of the meteors that crossed Ontario were estimated in degrees by seven different observers. The results range from 3 up to 50 miles, with an average of about 20. The estimate at Bermuda gives 15.

With regard to the speed of the meteors, the only one that we can identify with any certainty is the bright white one that we believe was composed of iron. If this occupied the middle of the train in Ontario, we see by Table I that it must have passed at $9^h\ 08^m.5$ E. S. T. or $14^h\ 08^m.5$ G. M. T. We have no record of the time in the United States, nor in Bermuda. The two times given by the Bellusia were given from memory, and both appear to be hopelessly wrong, unless indeed Mean time was employed. If so, that fact is not stated. Fortunately the officer on the watch on the Newlands timed the meteors, and gives it as $12^h\ 13^m$ Local, Apparent. This reduced to Greenwich for his longitude, 32° 30′, gives us $14^h\ 37^m.5$.

Unfortunately he does not state definitely what he timed, whether it was the very bright meteor which first attracted his attention, and to which he refers in the quotation given above, or whether it was the beginning of the procession which followed. If the former, then the time required by the iron meteor to travel from Ontario to the point where it was observed from the Newlands was 29 minutes. If the latter, and the meteors preceded the procession by let us say a minute, the time of transit was 28, and the time taken by the head of the procession 32 minutes. It is possible that he timed the middle of the procession, which would reduce the last two figures by 3 minutes. Whatever he timed will not make a very great difference, and we shall perhaps be safe in assuming that it was the head of the procession, and that therefore the time of transit of the iron meteor from Ontario to the Newlands was 28 minutes. The distance was 4353

miles. This would make its mean speed 2.59 miles per second. Professor Chant in his first paper on the meteors (Journ. R. A. S., Canada 1913, **7**, 159) estimates the speed in Ontario at between 5 and 10 miles. In his third paper, p. 447, he reduces his limits to between 6 and 6.5 miles. Mr. Denning on p. 441 estimates it at 8 miles, and Mr. Davidson, p. 441, at 5.15. The theoretical speed for a circular orbit around the earth at a height of 35 miles is 4.89 miles per second.

It would therefore seem at first sight as if a mean speed of 2.59 miles per second was impossibly slow. It would be so for a continuous orbit, but this orbit was not continuous, since the meteors struck the surface of the sea at a distance of about 700 miles southeast of the Newlands. In fact they had reached the Bellusia, which appears to have been near the location of their apogee, when they were 45 miles above the sea. They seem to have followed pretty closely an elliptical orbit, with but little deviation caused by atmospheric resistance. Their apogee was nearly opposite the sun, and their perigee, had they ever reached it, would have been at a distance of 3522 miles from the center of the earth; eccentricity of orbit 0.064.

These results are readily obtained by means of the well known formulae $\mu = g\,s^2$ and $v^2 = 2\mu(1/r - 1/s)$, whence $r = 2s\mu/(s\,v^2 + 2\mu)$, where g is the force of gravity, v the velocity, and s the distance at apogee, while r is the distance at perigee. The Bellusia station, which the meteors crossed when nearest that ship, is 36°.79 from the Ontario station, and 26°.49 from that of the Newlands. Since the meteors were retarded chiefly towards the end of their course, we have taken the speed at the Bellusia as identical with the mean speed 2.59 miles per second.

In order to check these results we have computed the height that the meteors should have had, in following this orbit, when they passed the Newlands. The result comes out 17.6 miles. The observed height from that ship, as we have already seen in our first paper, Table I, was 14 miles. The atmospheric resistance would reduce the computed height somewhat, and the observed angular height may not be quite correct, so that the size of the deviation after a course of nearly 2000 miles may be considered as satisfactory, and the evidence good in favor of the computed orbit and adopted speed.

In our next paper we shall bring forward some corroborative evidence regarding the speed, which came to light after the present article was practically finished. We shall discuss also the size of the meteors, and their resemblance to certain other displays, accounts of which have been handed down to us from the past.

Mandeville, Jamaica, B. W. I., Nov. 9, 1922.

PLATE V.

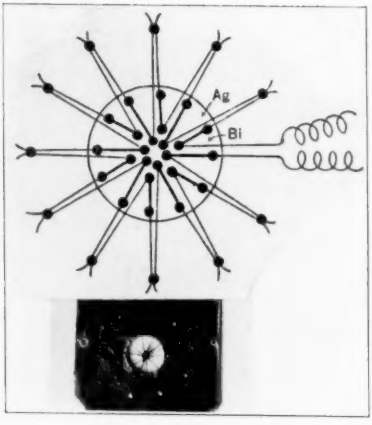

FIG. 1.

Stellar Thermopile of March, 1911.
Receiver: 1 mm diameter
Sensitivity = 5 × Nichols stellar radiometer.

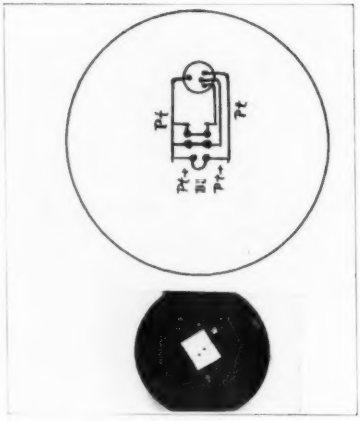

FIG. 2.

Stellar Thermocouples of 1913 and 1914.
Receivers: 0.3 mm diameter.
Sensitivity = 150 × Nichols stellar radiometer.

FIG. 3.

STELLAR THERMOCOUPLE IN VACUUM CONTAINER.

THERMOCOUPLE MEASUREMENTS OF STELLAR AND PLANETARY RADIATION.*

By W. W. COBLENTZ.

I. Introduction.

It is beyond the scope of this paper to discuss the early attempts at measuring the heat from stars.† Suffice it to say that these early attempts[1 to 9] are the milestones along the way to present day developments, just as one may expect the present measurements to be supplanted by others which will be obtained with improved apparatus and under more favorable conditions.

The first precise instrument for measuring thermal radiation was probably the thermopile. It was made of blocks of bismuth and antimony and because of its great heat capacity, a long time was required to obtain an indication of temperature equilibrium on exposure to thermal radiation.

Nevertheless, in the hands of Melloni and of Tyndall, it opened new fields of research on properties of matter as affected by the emission, absorption and reflection of thermal radiation. That occurred some three to fourscore years ago, and ever since then numerous investigators have been occupied with various optical problems which can be investigated best by means of thermal radiometers.

In the meantime, other radiometric instruments were invented, including the Langley bolometer and the Nichols radiometer. Incidentally it may be noted that the last mentioned device was the first to force the attention of the scientific public to acceptance of the successful measurement of thermal radiation from stars. This seems to have become now a convenient criterion for judging the sensitivity of a newly devised radiometer.

It is to be noted that the bolometer functions by changing the resistance of a thin blackened strip of metal (usually platinum) as a result of warming by absorption of thermal radiation. This thin strip of metal forms one or more arms of a Wheatstone bridge, which requires an external battery for operation. The platinum receiver can be made extremely thin (the writer has used material less than 0.0003 mm thick) of low heat capacity, hence quick acting and highly sensitive to weak thermal radiation. In fact, the bolometer has always had the reputation of being the most sensitive of thermal radiometers.

In contrast with the bolometer, the thermocouple requires no special battery, for, when exposed to thermal radiation it generates an electri-

*Paper presented by invitation before the Optical Society of America, Meeting of October 26, 1922; at the Bureau of Standards, Washington, D. C.

†References to the literature are given at the end of this paper.

cal current which is proportional to the intensity of the incident radiation. Like the bolometer, it is non-selective to radiation of different wave-lengths, hence it is applicable to the solution of the same problems as is the bolometer.

One of my duties on first arrival at this Bureau, was to develope and intercompare instruments and methods of radiometry. It was found (after using this instrument extensively for almost 5 years) that while the bolometer is a very sensitive radiometer, with its auxilliary battery and balancing rheostat it is at best a cumbersome installment; too complex to be placed in the hands of botanists, light-therapists, mycologists, physiologists, psychologists and zoologists (not mentioning physicists and, may I add, astronomers) who have need of a simple, yet sensitive, non-selective radiometer to measure the intensity of the light stimuli used in their investigations.

The story of the development of a highly sensitive, quick-acting thermopile, to meet the demands of the above mentioned investigators is written so that all may read.[10, 11] Suffice it to add that the adoption of the technique of construction as well as the design of the thermocouple radiometer, by astronomers, seems gratifying.

An interesting side-line, which forms the subject for discussion this afternoon, was the construction and intercomparison of thermocouples of sufficient fineness and hence low heat capacity to measure the heat from stars[10] and isolated spots in the images of the major planets. For the latter purpose, the small disk-receiver of a thermocouple is probably better adapted than is a (linear) bolometer. No doubt, the bolometer still remains the more sensitive of these two types of non-selective radiometers. But the fact that the recent researches of various investigators have brought the thermopile to such a state of perfection that it is a close competitor with the bolometer in sensitivity, quickness of action, adaptability, and simplicity of operation, shows that their efforts have not been in vain, and lends hope that, as it was the first in the field, it will always remain there.

Not until radiometric work was recently undertaken in connection with the great 100-inch reflector at Mt. Wilson, has the stellar thermocouple had a chance to demonstrate its usefulness. Previous tests were made with thermocouples and with galvanometers carried several thousand miles and used on improvised piers; the apparatus being set up and in operation in two or three nights after arrival. This fact shows the simplicity of the outfit. Owing to the temporary nature of the set up, the galvanometer could not be used at its full sensitivity. Nevertheless, in spite of these handicaps useful information was obtained which has commanded the attention of astronomers. Indeed, since writing this paper, one eminent authority (Russell, The Sci. American, Nov. 1922) has expressed his belief that the thermocouple "promises to be one of the most important instruments of future investigation" in astronomy.

II. Development of Stellar Radiometers.

Before taking up a discussion of the stellar radiometric measurements, it may be of interest to notice the historical development of the stellar thermocouple as constructed and used by the writer. In Fig. 1, Plate V, the photograph No. 1 shows a thermopile constructed[10] and tested in March, 1911. It consisted of ten junctions of bismuth and silver, meeting at a point and backed by an insulated receiving disk of tin 1 mm in diameter. The candle test showed that this form of thermocouple could easily be made four to five times as sensitive as the Nichols stellar radiometer.[10]

An examination of photographic star images showed that only a small sized thermoelectric receiver would be required to intercept all the incident stellar radiation. It was therefore decided to use a single thermocouple, instead of a thermopile, constructed of the finest wires that could be made, the receivers being of the order of 0.3 to 0.35 mm in diameter.

The photograph No. 2, Fig. 2, Plate V, shows such a thermocouple of bismuth-platinum (receivers 0.3 mm in diameter) mounted on a fiber base, constructed for use with the 26-inch refractor of the U. S. Naval Observatory, in the summer of 1913. However, this instrument being available only on Sunday nights, with uncertain weather conditions and, having the opportunity presented to use the 36-inch Crossley reflector of the Lick Observatory during the summer of 1914, the first astronomical tests of stellar thermocouples were deferred until the following year. In the meantime, thermocouples were constructed and their sensitivity tested on the fiber mounting No. 2. The sensitive couples were then mounted (as shown in the diagram in the center of Fig. 1) for use in the vacuum chamber[11, 8] shown in Fig. 3, Plate VI. In this illustration, *T* is the thermocouple, *F* is the fluorite window, *P* the potential terminals for testing the evacuation and *Ca* the metallic calcium which is used to maintain a vacuum.

The sensitivity of such a thermocouple is 150 to 200 times that of the Nichols stellar radiometer, or 40 to 50 times the above described point-receiver thermopile.

Just as the stellar radiation measurements were begun (July-August, 1914) civilization was given a rude shock. Seven long distressing years had to pass by before the stellar radiometric work could be resumed.

The design of the thermocouples used in 1921 and 1922 remained practically the same as used in the earlier work. But the receivers were made smaller (0.2 mm) for use in measuring the intensity of the radiation from particular regions of the image of a planet. An innovation was the employment of a spectral radiometer[9] consisting of a series of transmission screens and a vacuum thermocouple. The vacuum thermocouple container in its mounting and the transmission screens are shown in Fig. 4, Plate VI. The diagram in the lower left hand cor-

ner shows the construction of the thermocouples; usually two in a cell.

By means of these screens (of blue, yellow and red glass, quartz, water, etc.), which either singly or in combination, had a uniformly high transmission over a fairly narrow region of the spectrum, terminating abruptly to complete opacity in the rest of the spectrum, it was possible to obtain the component radiations in successive spectral regions, and hence some idea of the radiation intensities (the spectral energy distribution) in the complete stellar spectrum (from 0.3μ to 10μ) as transmitted by our atmosphere.

TABLE 1.—Comparison of the Total Radiation from Stars Having Closely the Same Visual Magnitude. Measurements of 1914 and 1921.

Star	Spectral Class	Visual Magnitude	Galvanometer Deflection
			cm
α Aurigae	Go	.21	4.91
α Boötis	Ko	.24	8.10
α Aquilae	A5	.90	1.89
α Tauri	K5	1.06	6.03
α Orionis	Ma	.92	15.0
β Geminorum	Ko	1.21	2.19
α Scorpii	Map	1.22	8.82
α Coronae Borealis	Ao	2.32	.48
β Ursae Majoris	Ao	2.44	.37
γ Draconis	K5	2.42	1.65
γ Leonis	Ko	2.61	.99
β Pegasi	Mb	2.61	2.96
δ Capricorni	A5	2.98	0.28
β Aquarii	G	3.07	0.55
ρ Ophiuchi	Ko	2.94	.37
δ Ophiuchi	Ma	3.03	1.37
ε Geminorum	G5	3.18	0.58
μ Geminorum	Ma	3.19	2.11
θ^2 Tauri	A5	3.62	0.18
ε Tauri	K	3.63	0.35
ν Tauri	A	3.94	0.12
γ Tauri	G	3.86	0.36
δ Tauri	K	3.93	0.52
γ Aquarii	A	3.97	0.24
λ Aquarii	Ma	3.84	1.02
δ Ceti	B2	4.04	0.08
ν Ceti	Ma	4.18	0.31
φ Pegasi	Ma	5.23	0.22
19 Piscium	N	5.30	0.46

III. Measurements of the Total Radiation from Stars.

The method of observation consisted in projecting the star image alternately upon the two junctures of the thermocouple, by turning the slow motion screws of the plate holder or by tilting the telescope tube,

PLATE VI.

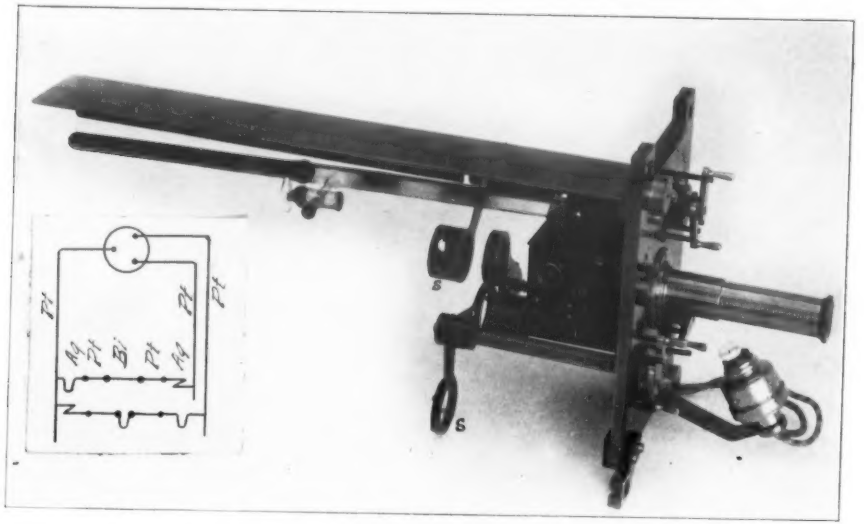

FIG. 4.

Mounting for Stellar Thermocouple Container, Fig. 3, and Transmission Screens, S. Inset, diagram of thermocouple used in 1922.

and noting the change in the galvanometer deflection as observed with the telescope scale, which was at a distance of 2 m.

The great difference in the total radiation from stars is well illustrated in Table 1, which gives a comparison of the total radiation from groups of stars having closely the same visual magnitude. This is an interesting assortment, ranging in stellar magnitude from 0.2 to 5.3. The measurements made at Mt. Hamilton, Calif. (Lick Observatory, altitude 4000 ft.), in 1914 were verified in 1921 at Flagstaff, Ariz. (Lowell Observatory, altitude 7250 ft.), showing that the early-type (Class M - N) red stars are losing heat by radiation 3 to 4 times more rapidly than the more dense but hotter late-type (Class B - A) blue stars of the same visual magnitude.

The least dense, class M, stars must therefore be losing heat by radiation, in which conduction does not contribute very materially in maintaining the surface at a given temperature.

In the dense stars, the shape of the spectral energy curve, and hence our inferences of the effective temperature, is determined by the spectral emissivity of the surface; while in the less dense stars the radiation emanates from great depths.

Now that we have this information, it may be said that the observations confirm what should be expected. For, in one sense, we are comparing the radiant luminous efficiency of red stars with that of blue stars (of the same visual magnitude) and from the laws of radiation one would expect the red stars to have the lowest luminous efficiency.

IV. Measurements of the Stellar Radiation Transmitted by a Cell of Water.

The comparison of the total radiation from red and blue stars of the same photometric brightness is somewhat uncertain because the radiation received from a star is a function of its size, distance, temperature and especially its emissive power.

It was therefore desirable to obtain some check-measurement in which these factors are eliminated. This was accomplished in the measurements of 1914 by separating the star's rays roughly into a spectrum, by means of a 1-cm cell of water which absorbs most of the infra-red rays and transmits the visible and ultra-violet rays. Hence, by measuring the total radiation from a star, and also the part which is transmitted by the absorption cell of water, we obtain an estimate of the relative amounts of energy in these two parts of the spectrum. This measurement is a ratio of two intensities of radiation; and it is independent of the size, the distance and the temperature of the star. It gives us direct information of the emissivity in the different parts of the star's spectrum. It is true that it gives us information of only two parts of the spectrum; but as will be noticed presently in the measurements of stellar temperatures, obtained in 1921, the water cell is sufficient for the purpose.

The measurement of the stellar radiation transmitted by the water cell is a quick and an efficient means of determining the infra-red radiation from stars. The observed transmissions for the blue, B and A class stars (which have no dark companion stars), are as high as 82 per cent, and if a correction had been made for absorption by the silvered mirrors the transmission would be still higher. Since the maximum observable transmission through (including surface reflec-

TABLE 2.—Transmission of Stellar Radiation Through 1 cm Layer of Water. Observations of 1921.

Star	Magnitude Relative	Magnitude Absolute	Luminosity[a]	Spectral type	Transmission per cent	Remarks
ϵ Orionis	1.75			Bo	81	
γ Orionis	1.70			B2	82	
β Tauri	1.78			B8	79	
β Orionis	.34			B8 p	*63	(Rigel) spectroscopic binary
α Geminorum	{ 1.99 } { 2.85 }			Ao	82	(Castor)
α Lyrae	.14			Ao	75	(Vega)
α Canis Majoris	{ −1.58 } { 8.5 }			Ao	*65	(Sirius) binary
α Cygni	1.4			A2	76	(Deneb)
α Aquilae	.9			A5	71	(Altair)
α Persei	1.9	+0.3	75.9	F5	74	(Suspected binary)
α Canis Minoris	{ .48 } { 13.5 }	+3.1	5.75	F5	*64	(Procyon) binary
α Aurigae	.21	+ .3	75.9	Go	*57	(Capella) spectroscopic binary
ϵ Geminorum	3.18	−1.0	251.	G5	66	
β Geminorum	1.21	+ .8	47.9	Ko	58	(Pollux)
α Boötis	.24	+ .9	43.7	Ko	47	(Arcturus)
α Tauri	1.06	+ .9	43.7	K5	42	(Aldebaran)
λ Aquarii	3.84			Ma	47	
μ Geminorum	3.19			Ma	41	
β Andromedae	2.37	+1.6	22.9	Ma	41	
α Orionis	.92			Ma	34	(Betelgeux)
α Scorpii	1.22	−3.0	1584.	Ma p	*33	(Antares) spectroscopic binary
β Pegasi	2.61	+1.3	30.2	Mb	38	

[a]Adams and Joy, Astrophys. J., **46**, p. 313; 1917.

tion from) the water cell can be only about 91 per cent, and since the water cell absorbs but little radiation of wave-lengths less than 0.9μ, it appears from this high transmission that, in blue stars, there is but little infra-red radiation of wave-lengths greater than 1μ. Assuming that the energy distribution is similar to that of a black body, the transmission data indicate that the maximum emission lies in the ultra-violet. From this it appears that much information on the spectral energy distribution of blue stars can be obtained by means of the photographic plate.

In Table 2 the water cell transmissions are arranged in the order

of the spectral class of the star. These data confirm the direct measurements showing that the red stars are losing heat by radiation much faster than blue stars of the same visual magnitude. In this same table, data are given on the absolute magnitudes and the luminosities of some of the stars. Although these data are meager they seem to show that, comparing stars of the same absolute magnitude, the red stars emit the greatest amount of radiation.

As already stated, the absorption cell is useful because its functioning is independent of the size or the distance of the star. It indicates that the shape of the spectral energy curve of the star is such that only about one-fourth of the total energy emitted by a red star lies in the visible and in the ultra-violet part of the spectrum. However, it should dispel all doubt as to the quality of the radiations emitted by red and by blue stars. The absorption cell does more than merely tell us the region of the spectrum in which the most energy is distributed. It may prove useful in detecting dark companions of binary stars. This is shown in the measurements on binary stars in Table 2, in all cases of which the water cell transmission is lower than that of a single star of the same spectral class.

There are no doubt many visible stars having companions which have become so cool and nonluminous that their presence cannot be detected photographically. Hence, the water cell (having the property of absorbing the invisible infra-red rays) should be useful in searching for double stars having dark companions.

Some thermocouple measurements on a variable star (α Herculis) made in 1914 foreshadowed the usefulness of the device in this field. Indeed, judging from a recent paper by Pettit and Nicholson[12] on some thermocouple observations at Mt. Wilson, on the total radiation from variable stars of long period, a continuation of this interesting subject seems assured. Using the 100-inch Hooker telescope, stars were measured of visual magnitude as low as 9.2, the water cell transmissions in some cases, being as low as 20 per cent of the total radiation from red, class M stars, thus showing the great amount of infra-red radiation contributed by the dark companion stars.

As already stated, the measurements made with the water screen show that, in blue and yellow stars, practically all the energy lies in that part of the spectrum to which the photographic plate is sensitive. Hence, since the effect on the photographic plate is cumulative, and the time for exposure is relatively unlimited, the spectral energy distribution of many weak stars and nebulae can be mapped, which will not be possible by any other methods known to us at the present day. Indeed such a beginning has been made recently by Plaskett.[13] But the measurements made through the water cell show that if astronomers had known it, they could have used the photographic method long ago for determining the spectral energy distribution of blue and yellow stars. For this purpose, the photographic plate must, of course,

be standardized by exposing it to the spectrum of a source of known spectral energy distribution, as was done, for example, by Ives and Coblentz[14] in determining the spectral energy distribution in the light of the firefly.

The water cell measurements open up a new line of thought on stellar evolution, showing, as already stated, that red stars are losing heat 4 times as fast as blue stars. From present theories it appears that in the Giant red-star stage of evolution, a star may be rising in temperature, while it is decreasing in temperature on its return to the Dwarf (red-star) stage.

A question of interest is whether, when the star is passing through the high temperature, blue, class B, A-stage of development (and is losing heat one-fourth as fast as when it is in the red, class M-stage) the interval of time of transition is relatively much longer (say 3 to 4 times longer) than when the star is in the low-temperature, red, class M, N-stage of evolution.

V. Stellar Temperatures from the Energy Distribution in the Complete Spectrum.

The hundreds of photographs of stellar spectra, obtained by astronomers, show dark absorption lines and bands (also in some cases, bright emission lines) of hydrogen, helium, etc. From this it is evident that a smooth spectral energy curve, without deep indentations, cannot be obtained. Our inferences as to the probable spectral energy distribution and inferred effective temperatures of stars must therefore be obtained by smoothing over the depressions in the observed spectral energy curve. Then, assuming that the stellar envelope radiates like a gray or black body, the effective stellar temperature may be calculated.

At best, a spectroscope is an inefficient device for utilizing the incoming stellar radiation. In 1921, the 40-inch reflector of the Lowell Observatory was placed at my disposal to test the method of obtaining the spectral energy distribution of a star by means of a series of transmission screens, placed in front of a vacuum thermocouple as shown in Fig. 4, Plate VI.

By means of these screens, as already described, it was possible to obtain the radiation intensity in the spectrum (from the extreme ultraviolet, which is limited by atmospheric transmission and the low reflectivity of the telescope mirrors) at 0.3μ, to 0.43μ; 0.43μ to 0.60μ; 0.60μ to 1.4μ; 1.4μ to 4.1μ; and 4.1μ to 10μ.

The distribution of energy in the spectra of 16 stars was determined, thus obtaining for the first time an insight into the radiation intensities in the complete spectrum of a star.

This method may be open to criticism in view of the fact that it integrates the energy present in a certain spectral region, and hence does not indicate the amount lost in the spectral absorption lines. The

same criticism is true also of the direct spectro-bolometric method which is no doubt limited to a few of the brightest stars and if the dispersion is small, cannot properly evaluate the spectral intensities. Hence the transmission screen method should prove useful in supplementing the spectro-radiometric measurements on faint stars not measurable by the latter method.

By means of this spectral transmission screen device, it was found that, in the class B and class A (blue-white) stars, the maximum radiation intensity lies in the ultra-violet (0.3μ to 0.4μ) while in the cooler, class K and M (red) stars, the maximum emission lies at 0.7μ to 0.9μ in the infra-red.

TABLE 3.—Stellar Temperatures.

Star	Class	Coblentz Calculated	Coblentz Class G0 as standard	Wilsing Scheiner, and Münch	Nordmann and Le Morvan	Nordmann	Saha
		° K	° K	° K	° K	° K	° K
ε Orionis	Bo	13 000-14 000	13 000				18 000
β Orionis	B8p	10 000-12 000	10 000				
α Lyrae	Ao	8000-10 000	8000	9400		12 200	
α Canis Majoris	Ao	8000-11 000	8000				12 000
α Cygni	A2	8000-10 000	9000	9400			
α Aquilae	A5	7000-9000	8000	8100			
α Canis Minoris	F5	5500-7500	6000	7200			
α Aurigae	Go	5300-6500	6000	7100			7000
α Boötis	Ko	3500-4500	4000	3700			
β Geminorum	Ko	4500-7000	5500	4900			
α Tauri	K5	2800-4500	3500	3500	3600	3500	
α Orionis	Ma	2800-3300	3000	3000			5000
α Scorpii	Map	2500-3200	3000				
β Andromedae	Ma	3500-4500	4000	3200	4300	3700	
μ Geminorum	Ma	2500-3300	3500	3100	3200		
β Pegasi	Mb	2500-3200	3000	2800			
Sun	Go		[a]5800-6200			5320	

[a]Recalculated from Abbot and Fowle, Jour. Opt. Soc. Am., **5**. p. 272; 1921.

An estimate of the effective temperature of a star was obtained by comparing the observed spectral radiation components with the calculated values for a black body at various temperatures. From this it appears that the black body temperature (i. e., the temperature which a black body would have to attain in order to emit a similar relative spectral energy distribution) varies from 3000° K for red, class M, stars to 12,000° K for blue, class B, stars.

In Table 3 are assembled various determinations of the effective stellar temperatures by Nordmann,[15] and by Nordmann and Le Morvan;[16] also by Wilsing, Scheiner and Münch,[17] all of which relate to observations in the visible spectrum; also calculated values by Saha[18] on the basis of ionization theory.

While it is to be expected that the various methods must give different results, it is interesting to find a rather close agreement in the estimated stellar temperatures. The agreement is especially close for stars of classes G, K and M, that is, stars having a low temperature.

VI. Measurements of Planetary Radiation.

By planetary radiation is meant the emission of thermal radiation from a planet as a result of warming of its surface by exposure to solar radiation, including heat radiated by virtue of a possible high internal temperature of the planet itself.

The temperature of the surface, due to absorbed solar radiation and due to internal heat, at most, is probably not much higher than several hundred degrees centigrade and hence the re-radiated energy (which is transmitted by the earth's atmosphere) will be predominately of long wave-lengths, — 7 to 14μ. Hence by means of a 1 cm water cell interposed in the path of the total radiation emanating from the planet, this long wave-length radiation can be separated from the reflected solar radiation, and in this manner a measurement obtained of the planetary energy radiated. If there is planetary radiation, then the water cell transmission will be less than that of the direct solar radiation. It appears to be relatively unimportant whether a screen is used which is opaque to radiations longer than 1.4μ (a water cell) or a screen which is opaque to wave lengths greater than 4.2μ (quartz cell). For, if there is planetary radiation, the transmission will be different from that of the direct solar rays, whatever the cell that is used.

By comparing the transmission of the direct solar radiation, through a water cell, with the transmission of the radiation emanating from the planet, a measurement was obtained of the intensity of the planetary radiation.

During the past June, the writer made further measurements (at the Lowell Observatory) of the thermal radiation emitted by the major planets.

Radiometric measurements were made on Venus, Mars, Jupiter, Saturn and the Sun, and in cases where similar measurements had been made at Mt. Hamilton, Calif., in 1914, the data were found in good agreement.

The water cell transmissions of the radiation from the planets is given in Table 4. These measurements show an interesting sequence of water cell transmissions which decrease (i. e., the per cent of planetary radiation increases) with decrease in thickness and density of the planetary atmospheres; Jupiter (69), Venus (66), Saturn (60), Mars (50), and the moon (15). The per cent difference between the water cell transmission (69 per cent) of the direct solar radiation and that of the radiation emanating from the planet is a measure of the

planetary radiation, and is as follows: Jupiter (0), Venus (5), Saturn (15), Mars (30), and the Moon (80).

These data, as just stated, show that the order of intensity of the planetary radiation, as interpreted from measurements of the total radiation emanating from the planet which is transmitted through a cell of water, is as follows: Jupiter (the least), Venus, Saturn, Mars and the Moon (the greatest). This planetary radiation may consist of (1) the energy re-radiated as the result of heating of the planet (including both the surface and the atmosphere, if the latter emits radiation) by solar rays, (2) the energy which may be radiated owing to a high internal planetary temperature, if such a condition obtains, and (3) solar radiation which may be selectively reflected from the planet (including surface and atmosphere). In order to estimate the

TABLE 4.—Transmission of Planetary Radiation Through a Cell of Water 1 cm in Thickness; also the per cent of Planetary Radiation Emitted.[a]

Object	Date June, 1922	No. of sets of measurements	Per cent Transmission Deviation from mean %	Mean Value 1922	Mean Value 1914	Planetary radiation in per cent of the total
Sun	17 11:30 A. M.	5	1.2	69.3		
	4:15 P. M.	4	0.5	69.8		
Jupiter	14					
Central disk	10:15 P. M.	2	1.4	69.7	65.6	0
S. polar region	10:20 P. M.	2	3.0	66.8	65.8	
Venus	15 8:00 P. M.	2	2.3	66.3	59.0	5
Saturn	14 9:00 P. M.	3	1.1	60.0	55.	15
Mars	15 and 18		6.0	50.3		30
Moon					14.7	80

[a] The complete data are given in Bureau of Standards Sci. Paper No. 460.

part contributed by each of these sources of long wave-length infrared radiation, it is necessary to consider other information on the planets.

1. *Planetary temperatures.*—In his theoretical investigation of the radiation from the solar system, assuming that the planets are similar to the earth, Poynting[19] calculated the following temperatures: Mercury 196° C., Venus 69° C., Earth 17° C., Mars —38° C. He omitted Jupiter and Saturn in view of the probability that they radiated heat of their own, in considerable proportion. Using more recent data on the solar constant would not affect these calculations in a marked degree. Calculations of this type[24] indicate a lunar temperature of 82° C. for the full moon.

Probably the most convincing experimental observations of the range of temperature of the moon are those of Langley and Very,[22] and later those of Very.[23] These measurements indicate inferred effective lunar temperatures ranging from 45° C. to over 100° C.

Lowell's[20] calculations of the surface temperature of Mars give values much higher than those obtained by Poynting and others; and they are in agreement with what one would expect from the radiation measurements recorded in the present paper. His calculations, taking into account factors previously neglected, and based on the heat retained, give a mean temperature of 48° F. (9° C.) for the surface of Mars; while another calculation gives a temperature of 22° C. He points out that owing to cloudiness, only 60 per cent of the incident solar radiation is effective in warming the earth while 99 per cent is effective in warming the surface of Mars. Other meteorological data of interest are that, on Mars, water boils at 44° C., that the amount of air per unit surface is 177 mm (2/9 the earth's) and that the density of the air at the surface is 63 mm (1/12 the earth's).

In a recent discussion of climatic conditions on Mars, inferred from phenomena generally observed on the planet, Pickering[21] estimates the mean annual temperature at +20° F. as compared with the mean annual temperaturue of the earth of +59° F. (15° C.). At night, the Martian temperature is below 32° F. (0° C.) and at noon it is perhaps 60 to 70° F. (15 to 20° C). These figures are arrived at from the appearance and disappearance of snow and frost during the course of the Martian day, and from the fact that snow is never seen on the equator at Martian noon.

2. *Selective Reflection of Solar Radiation.*—Investigations of infrared reflection spectra[25] show that silicates, carbonates and sulphates have the property of selective reflection in the region of the spectrum extending from 6μ to 10μ and the question arose as to the effect this would have upon the solar radiation reflected from a surface like the earth or moon, which is no doubt composed largely of silicates. In the region of selective reflection, the radiations that would ordinarily be emitted as a result of warming of the surface by absorption of solar radiation are suppressed. In that paper,[25] no estimate could be obtained of the selectively reflected solar radiation of wave-lengths 6μ to 10μ which is superposed upon the directly emitted lunar radiation.

More recent consideration of the phenomenon does not alter the conclusion that such a selective reflection must exist, if the planetary surface contains carbonates, sulphates and silicates. However, from an estimate of the probable magnitude of the selective reflection, and from the calculations of the temperature rise of the planets, it appears that, for the purposes of the present paper the planetary radiation may be considered practically free from selectively reflected solar radiation.

3. *Venus.*—The radiometric measurements on Venus are interesting in showing only a small planetary radiation. The planets Jupiter and Venus have practically the same visual albedos (Venus 0.59, Jupiter 0.56). They are subject to great differences of intensity of solar radiation, (Jupiter : Venus :: 1 : 57.5 approx. at the date of

observation) with only small planetary radiation,—Jupiter 0 per cent, Venus 5 per cent.

The intensity of solar radiation incident upon Venus is almost twice that incident on the earth. Their atmospheres are considered similar in constitution and hence one would expect a greater heating of the surface and of the lower atmospheric layers of Venus if the solar energy is transmitted by its atmosphere proportionately as on the earth. As mentioned above, Poynting calculated a surface temperature of 69° C. for Venus as compared with 17° C. for the earth. From these considerations, it is of interest to note that, owing to clouds, practically no planetary radiation (only about 5 per cent) escapes through the atmosphere of Venus. On clear nights, the terrestrial nocturnal radiation escaping to space is estimated[26] to be 10 to 20 per cent of the nocturnal radiation (0.1 to 0.2 gr. cal. per cm^2 per min.) intensity at the earth's surface. In cloudy weather practically no terrestrial planetary radiation escapes into space. From this, it appears that owing to cloudiness, convection of the atmospheric layers, etc., the escape into space of the planetary radiation from Venus and from the earth is practically nil.

4. *Mars.*—The transmission measurements on Mars were obtained by means of two thermocouples differing widely in construction. The diameters of the receivers were about 0.4 of the diameter of the planetary disk.

On June 18th, the intensity of the galvanometer deflection for the radiation emanating from the region of the southern hemisphere, the equator and the northern hemisphere was respectively 7.1, 8.2 and 5.4 cm. In this connection, it is interesting to note that while making observations on the equatorial region, meteorological conditions continued uniform for an hour, so that the observations at the beginning and the end are in agreement within one per cent.

The water-cell transmission of the radiations from the southern (50.6 per cent) and northern (53.1 per cent) hemispheres of Mars should be and are higher than that of the radiations emanating from the equatorial (47.3 per cent) region, owing to a smaller degree of heating of the polar regions (because in these regions the solar radiation traverses a greater air-mass and is incident at greater obliquity upon the Martian surface) and also owing to the depletion of the outgoing reflected and re-radiated energy by the same air-mass. At the time of the observations, the sun was only about two degrees north of the planet's equator, so that the insolation of each hemisphere was practically the same. Moreover, the declination of the earth on Mars was only about 7°, which simplified the comparison. Hence, from the positions of the earth and the sun as viewed from Mars, one would expect to obtain closely the same transmissions, provided these two regions become equally warmed, and provided there are no clouds to intercept the re-radiated energy. The observations obtained with two

thermocouples differing widely in construction and on different dates, are consistent in showing a lower water cell transmission (a higher re-emission) of thermal radiation from the southern hemisphere than from the northern hemisphere, which is visually the brighter of the two. From this one might hastily conclude that the dark, southern hemisphere emits more of the long wave-length radiation than does the north polar region. This is an instance where the explanation of the radiometric measurements appears to require supplementary observations. According to the photographic and visual observations of Mr. E. C. Slipher, which were in progress at the time of making the radiometric measurements, the north polar and temperate regions exhibited cloudiness which would tend to trap the re-radiated long wave length emission thus raising the values of the water cell transmissions. Hence the cause of the higher value of the water cell transmission of the radiation from the (brighter) northern hemisphere is to be ascribed partly to the presence of clouds, which trap the planetary radiation, and one cannot decide whether the dark areas of the southern hemisphere are bare ground which have become warmed or whether they consist of growing vegetation, which, according to the writer's temperature measurements* of growing terrestrial plants, does not rise in temperature much above that of the surrounding air.

From the foregoing discussion of selective reflection, it seems reasonable to assume that the great amount of infra-red radiation from Mars is the result of an appreciable temperature rise of the surface. On the other hand, the low density of the Martian atmosphere would permit rapid cooling of the unilluminated surface, with the formation of snow and frost as observed. All evidence supports the view that the surface of Mars becomes appreciably heated by solar radiation with the consequent high emission of infra-red radiation as observed. This is in agreement with conclusions as to the radiation from the moon, the illuminated surface of which no doubt becomes highly heated, with the consequent high emission of infra-red rays, as observed.

Concerning the difference in the radiation from the northern and the southern hemispheres of Mars, it is of interest to record that, when the observations were in progress, the winter season was approaching in the northern hemisphere, when one would expect cloudiness and when on many previous oppositions it was observed that the poles were hidden in a mist. The radiometric measurements show a decidedly lower total radiation from the northern hemisphere in spite of the fact that it is the brighter visually and photographically. This is of

*Ann. Report of the Director of the Bur. of Standards, 1916. On p. 93, the Report of the Section on Radiometry shows that the temperature of growing leaves, in direct sunlight, may be 5 to 6° higher than that of the surrounding air, while the unilluminated leaf, owing to evaporation of moisture, is at a lower temperature than the air.

course to be expected in view of the approaching winter season on the north hemisphere, when the surface is cooling (hence a lower planetary radiation) and the outgoing planetary radiation is being trapped by increasing cloudiness.

The observations of Langley, Very, Julius, Boeddicker, etc., show that during an eclipse of the moon, there is a sudden and very rapid fall in temperature and intensity of thermal radiation at the beginning of the eclipse, and an equally rapid increase in infra-red radiation after its conclusion. From this and from our knowledge of terrestrial conditions, it seems that there is probably no marked lag in the cooling (or warming) of the Martian surface with change in season.

The radiometric measurements show that about 30 per cent of the total radiation from Mars is planetary, as the result primarily of warming of the surface by solar radiation. Such a rise in temperature, as already mentioned, is in agreement with other meteorological data bearing on this subject. In fact, these measurements confirm other observational evidence that the Martian surface becomes appreciably warmed by solar radiation.

5. *Jupiter.*—The water cell transmissions of the radiation from Jupiter were determined with a thermocouple receiver which intercepted about 1/4 of the image of the disk of the planet. The data are given in Table 4, from which it may be noticed that the value of the transmission is practically the same (69 per cent) as that of the direct solar radiation; also that the observations are in agreement with those obtained in 1914, at Mt. Hamilton, which is at a considerably lower altitude. From this it appears that the outer atmosphere of Jupiter does not emit appreciable infra-red radiation (of wave-length 7 to 14μ) as the result of warming by solar rays and by internal heat, and that the atmosphere is sufficiently thick and opaque to trap all the energy radiated as the result of heating of its interior by solar radiation, or that may be emitted as a result of a high internal temperature if such a condition exists.

An explanation can be given to the observations that the outer atmosphere of Jupiter does not emit an appreciable amount of infra-red radiation. Only those constituents (e. g. water vapor, ozone and carbon dioxide) which have absorption bands in the region of 6μ to 14μ will become heated by absorption of the long-wave-length radiation. Other constituents (e. g. oxygen, hydrogen, nitrogen, helium, etc.,) which are transparent to these radiations, will become heated only by conduction (and convection), and the average temperature and emission of long-wave-length infra-red radiation will be lower than would obtain if all the constituents were absorbing radiation. The infra-red radiation absorbed by some of the gases is dissipated by conduction and convection to the great mass of atmospheric constituents which cannot emit radiation (at the low temperatures which

prevail) and there is no appreciable emission of long-wave-length (7 to 14μ) thermal radiation, as observed. Radiation of wave-lengths 4 to 7μ, and of wave-lengths greater than 14μ, which may be emitted by the outer atmosphere of Jupiter (and the other planets) will be absorbed by the earth's atmosphere, and hence cannot be observed.

6. *Saturn.*—The water cell transmission measurements were made on the center of the ball of Saturn, the diameter of the receiver being about one-half of the disk. At this time, the rings were too narrow and of too low intensity to measure radiometrically.

The transmission data are given in Table 4. The average value (60 per cent) of the water cell transmission is appreciably lower than that of the direct solar radiation, and it is in agreement with the observations of 1914, showing a considerable amount of infra-red radiation not present in the direct solar radiation.

From 12 to 15 per cent of the total radiation emanating from the ball of Saturn is long wave-length, planetary radiation. Since the spectroscopic evidence indicates that the outer atmosphere of Jupiter and Saturn are qualitatively the same, it is to be inferred that the Saturnian atmosphere does not become heated (because of the greater solar distance, it receives perhaps only one-fiftieth of the solar radiation incident upon Jupiter) and emit infra-red radiation and that the observed planetary radiation which emanates from the interior of Saturn is not entirely trapped by its outer atmosphere, because of its lower density and low absorptivity of long wave-length infra-red radiations. In view of the relatively high planetary radiation (15 per cent) of Saturn which (because of its greater solar distance) one would expect to be less, if it is the result entirely of solar radiation, as compared with that of Mars (30 per cent) it appears probable that some of the radiation emitted by the ball of Saturn is the result of a high internal temperature.

In concluding the discussion, it may be added that, although the superficial condition of the planets is constantly changing, there is a marked agreement in the radiometric observations of 1914 and the present observations on Jupiter, Saturn and Venus.

7. *The Moon.*—No observations of the water cell transmission of the radiation from the moon were obtained this year for an air mass comparable with that through which the planetary measurements were obtained. Since the present (as well as the 1921) radiation measurements on all of the other objects are in agreement with the observations of 1914, it is to be assumed that the water cell transmission of the lunar radiation is of the order of 15 per cent (see Table 4) as observed in 1914. The water cell transmission of the radiation from the moon is low (15 per cent) indicating a large temperature rise of the lunar surface, due to heating by solar radiation.

As already stated, the writer's radiometric measurements are in

agreement with the calculations of Lowell, and with the arguments set forth by Pickering, showing a considerable rise in temperature of the surface of Mars. Furthermore, as already stated, the observations on the temperature of the moon by Langley and Very[22] and by Very[23] indicate inferred effective lunar temperature ranging from 45° C. to over 100° C.

When we consider that 30 per cent of the total radiation emanating from Mars is of planetary origin, as compared with 80 per cent from the moon, and that all the evidence shows that the lunar surface becomes appreciably warmed, it appears that there is also a considerable temperature rise (10 to 20° C.) of the surface of Mars as calculated by Lowell. In this respect, the radiometric measurements confirm other meteorological data, showing that at Martian noon the snow is melted, which could not happen if the temperature were —39° C., as some have calculated.

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OCCULTATION OF VENUS.

By FREDERICK SLOCUM.

The occultation of Venus on the morning of January 13 was observed by Mr. R. W. Bristol and the writer under rather unfavorable circumstances. The moon was low in the southeast, the altitude being 26° for immersion and 28½° for emersion. Clouds and poor seeing also interfered somewhat with the accuracy of observations but not with the beauty of the spectacle.

Before immersion several photographs of the moon and Venus were taken with the 20-inch refractor, using a color filter and Isochromatic plate. An exposure of eight seconds was necessary to get the moon through the clouds. Venus, however, is overexposed. The photographs shown in Plate VII were taken 16 and 6 minutes before immersion.

Just before immersion an eyepiece was slipped into the plate holder and the following times noted:

IMMERSION.

		h	m	s	
First cusp	Jan. 12	23	49	47	G. M. T.
Second cusp		23	53	25	
Second limb		23	53	47	

EMERSION.

Second cusp	Jan. 13	0	25	1	

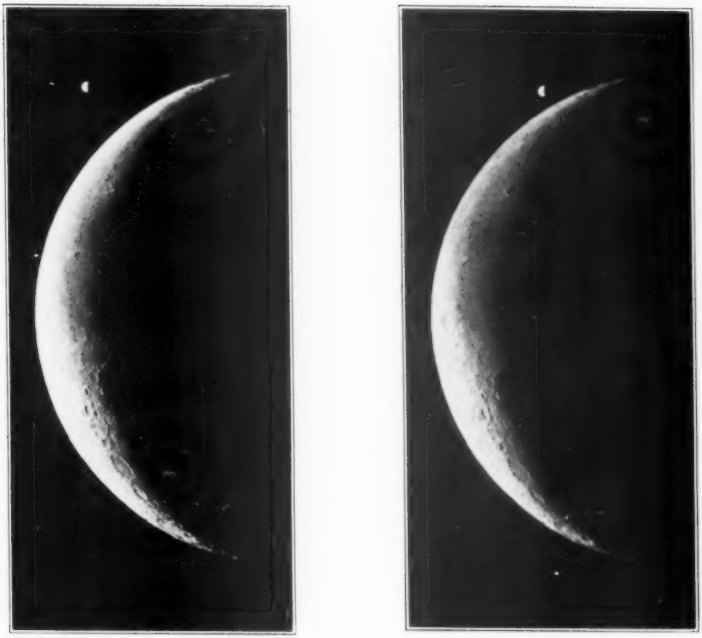
On account of the unsteadiness of the image the times are probably uncertain by 2 or 3 seconds. At emersion, clouds prevented the observation of the first cusp and the second limb. No trace of the first or dark limb of Venus could be seen. The dark shadings between the terminator and the bright limb of Venus were very conspicuous.

At immersion, as has been frequently noted before, the first cusp seemed to pass in front of, instead of behind, the moon. This was observed by both Mr. Bristol and myself. For a few seconds the cusp seemed to advance rapidly upon the moon's disk, then its motion was retarded, and after 10 or 15 seconds the cusp gradually withdrew behind the bright limb of the moon.

The dark limb of the moon could not be seen, and, if any such phenomena occurred there, the time of emersion will be much too early.

Van Vleck Observatory,
Middletown, Conn.

PLATE VII.



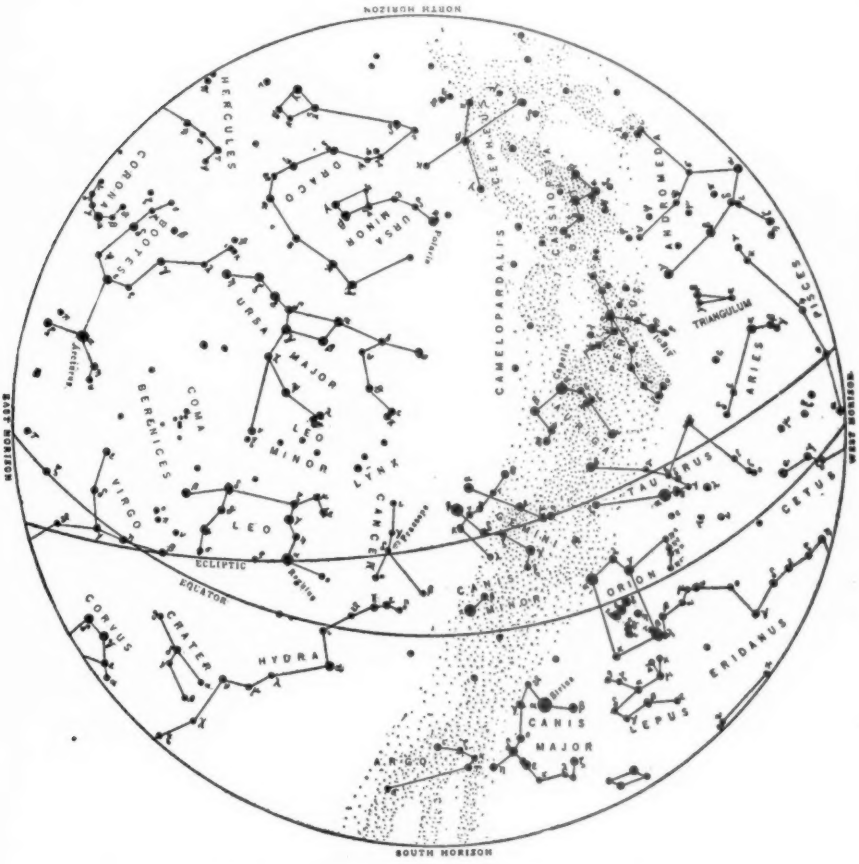
VENUS AND THE MOON, JANUARY 13, 1923.

Photographs taken by Professor Frederick Slocum, with the 20-inch refractor of the Van Vleck Observatory, Middletown, Conn., 16 and 6 minutes before the Occultation.

EAST HORIZON

PLANET NOTES FOR MARCH.

The *sun* will change its position from $22^h\ 46^m$ to $0^h\ 39^m$ and from $-7°\ 52'$ to $+4°\ 15'$ during the month. It will cross the equator about 3:30 P. M., Greenwich Mean Time, on March 21. This is the moment when spring begins according to almanac reckoning. The sun will pass from the constellation Aquarius into the constellation Pisces.



THE CONSTELLATIONS AT 9:00 P. M. MARCH 1.

The phases of the *moon* will occur as follows:

Full Moon	Mar.	2 at	9 P. M.	C. S. T.
Last Quarter		9 "	1 P. M.	"
New Moon		17 "	7 A. M.	"
First Quarter		25 "	11 A. M.	"

The *moon* will be nearest the earth for the month on March 4 and farthest from the earth on March 19.

Mercury will be west of the sun and will move eastward more rapidly than the sun during the month, and by the end of the month will be quite near the sun. It will not be in favorable position for observation at any time during the month.

Venus also will be following the sun eastward and gaining slightly on it. It is, however, about three hours west of the sun and will therefore be quite high in the eastern sky at sunrise. It will cross the meridian about 9:30 A. M. during the month.

Mars will continue its course eastward ahead of the sun. It will be low in the west at sunset. On March 15 it will cross the meridian at 2:54 P. M.

Jupiter will be well situated for observations in the morning during the month. On March 15 it will be on the meridian at 3:40 A. M. It will be between 16° and 17° south of the equator.

Saturn, which will be northwest of Jupiter, will be coming into position for evening study. At the end of the month it will be on the meridian at midnight.

Uranus will be in conjunction with the sun on March 4. It will therefore be too near the sun to be observed during the month.

Neptune will be on the meridian at 10:00 P. M. at the middle of the month and will consequently be very well situated throughout the month.

Occultations Visible at Washington.

[*From the American Ephemeris.*]

Date 1923	Star's Name	Magnitude	IMMERSION. Washington M.T.	IMMERSION. Angle from N	EMERSION. Washington M.T.	EMERSION. Angle from N	Duration
			h m	°	h m	°	h m
Mar. 3	27 B. Virginis	6.5	12 42	56	13 19	358	0 37
4	97 G. Virginis	6.5	10 52	143	11 53	266	1 1
7	49 Librae	5.4	18 13	132	19 21	250	1 8
9	305 B. Ophiuchi	6.3	18 15	44	19 13	321	0 58
20	25 Arietis	6.5	7 49	74	8 51	262	1 2
22	179 B. Tauri	5.9	10 22	150	10 47	202	0 25
23	318 B. Tauri	5.7	10 6	32	10 38	328	0 33
24	130 Tauri	5.6	8 44	98	9 58	269	1 13
25	26 Gemin.	5.2	9 29	92	10 40	286	1 11
28	ξ Leonis	5.1	10 27	106	11 41	298	1 14
29	48 Leonis	5.2	13 42	76	14 32	327	0 50
30	83 Leonis	6.3	10 14	101	11 28	311	1 14
30	τ Leonis	5.2	10 57	104	12 11	309	1 14

VARIABLE STARS.

RX Pavonis.—Estimates by Professor Bailey on fifteen photographs made at Arequipa, during the past season, of the variable RX Pavonis, *18h49m*, indicate variation in a long period between the photographic magnitudes 11 and 15. The variable was discovered at the Union Observatory by Wood in 1920, and found independently by Bailey in 1922.

Harvard College Observatory Bulletin 781.

Minima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1923							
					March							
	h m	° ′		d h	d h		d h		d h		d h	
SY Androm.	0 08.0	+43 09	9.5—13.0	34 21.8			7 12					
RT Sculptor.	31.5	—26 13	9.6—10.5	0 12.3	2 20		10 13		18 5		25 21	
U Cephei	0 53.4	+81 20	7.0— 9.0	2 11.8	1 20		9 8		24 7		31 18	
Z Persei	2 33.7	+41 46	9.4—12	3 01.4	6 17		12 20		25 1		31 4	
TW Cassiop.	37.6	+65 19	8.2— 9.0	1 10.3	8 8		16 21		25 11			
RY Persei	39.0	+47 43	8.0—10.3	6 20.7	6 20		13 17		20 14		27 10	
RZ Cassiop.	39.9	+69 13	6.9— 8.1	1 04.7	3 7		10 11		24 19		31 23	
TX Cassiop.	44.4	+62 22	9.4—10.1	2 22.2	2 4		10 23		19 17		28 12	
ST Persei	53.7	+38 47	8.5—10.5	2 15.6	6 2		14 1		21 23		29 22	
RX Cassiop.	2 58.8	+67 11	8.6— 9.1	32 07.6					20 11			
Algol	3 01.7	+40 34	2.3— 3.5	2 20.8	6 17		15 8		23 22			
RT Persei	16.7	+46 12	9.5—11.5	0 20.4	2 10		9 5		22 19		29 14	
λ Tauri	55.1	+12 12	3.3— 4.2	3 22.9	4 8		12 6		20 3		28 1	
RW Tauri	3 57.8	+27 51	7.1—<11	2 18.5	2 1		10 8		18 16		26 19	
RV Persei	4 04.2	+33 59	9.5—12.0	2 23.4	5 8		13 5		21 3		29 0	
RW Persei	13.3	+42 04	8.8—11.0	13 04.8			10 10		23 15			
SZ Tauri	31.4	+18 20	7.2— 7.7	3 03.6	8 15		18 2		27 13			
RS Cephei	4 48.6	+80 06	9.5—12.0	12 10.1			8 7		20 17			
TT Aurigæ	5 02.8	+39 27	7.8— 8.7	0 16.0	7 12		14 4		20 20		27 12	
RY Aurigæ	11.5	+38 13	10.7—11.7	2 17.5	9 0		17 4		25 8			
RZ Aurigæ	42.9	+31 40	10.6—13.3	3 00.3	1 13		13 14		19 14		31 15	
SV Tauri	45.8	+28 05	9.4—11.0	2 04.0	6 4		14 20		23 12			
Z Orionis	50.2	+13 40	9.7—10.7	5 04.9	4 21		15 7		25 16			
SV Gemin.	54.6	+24 28	9.8—<11	4 00.2	6 17		14 18		22 18		30 18	
RW Gemin.	5 55.4	+23 08	9.5—11.0	2 20.8	4 12		10 6		21 17		27 10	
U Columbæ	6 11.2	—33 03	9.2—10.0	2 19.2	6 10		12 0		23 5		28 2	
SX Gemin.	22.0	+20 37	10.8—11.5	1 08.8			11 4		19 9		27 13	
RW Monoc.	29.3	+ 8 54	9.0—10.8	1 21.7	3 20		11 11		19 2		26 17	
RX Gemin.	43.6	+33 21	8.8— 9.6	12 05.0			9 8		21 13			
RU Monoc.	6 49.4	— 7 28	9.8—10.5	0 21.5	8 1		15 5		22 9		29 13	
R Can. Maj.	7 14.9	—16 12	5.8— 6.4	1 03.3	7 22		14 18		21 13		28 9	
RY Gemin.	21.7	+15 52	8.9—<10	9 07.2	5 1		14 8		23 15			
Y Camelop.	27.6	+76 17	9.5—12	3 07.3	7 3		13 18		20 8		26 23	
TX Gemin.	30.3	+17 08	10.0—11.9	2 19.2	6 17		15 2		23 12		31 22	
RR Puppis	43.5	—41 08	9.4—10.7	6 10.3	4 13		10 23		23 20		30 6	
V Puppis	7 55.4	—48 58	4.1— 4.8	1 10.9	7 6		14 13		21 19		29 2	
X Carinae	8 29.1	—58 53	7.9— 8.7	0 13.0	2 22		11 1		19 4		27 7	
S Cancri	8 38.2	+19 24	8.2—10	9 11.6	9 14		19 1		28 13			
RX Hydræ	9 00.8	— 7 52	9.1—10.5	2 6.8	2 15		9 11		23 4		30 1	
S Velorum	29.4	—44 46	7.8— 9.3	5 22.4	3 11		9 9		21 6		27 4	
Y Leonis	9 31.1	+26 41	9.3—11.2	1 16.5	4 16		19 10		24 21		31 15	
RR Velorum	10 17.8	—41 36	10.0—10.9	1 20.5	1 6		8 16		23 12		30 23	
SS Carinæ	10 54.2	—61 23	12.2—12.8	3 07.2	2 21		9 11		22 16		29 6	
ST Urs. Maj.	11 22.4	+45 44	6.7— 7.2	8 19.2	3 14		12 9		21 4		30 0	
RW Urs. Maj.	35.4	+52 34	10.3—11.4	7 07.9	8 1		15 9		22 17		30 1	
Z Draconis	11 39.8	+72 49	9.9—13.6	1 08.6	6 17		13 13		20 7		27 2	
RZ Centauri	12 55.6	—64 05	8.5— 8.9	1 21.0	9 1		16 13		24 1		31 12	
RS Can. Ven.	13 06.3	+36 28	7.5—12.5	4 19.1	4 9		14 1		23 14			
SS Centauri	07.2	—63 37	8.8—10.4	2 11.5	8 1		15 10		22 21		30 7	
133926 Hydræ	13 39.0	—26 23	8.6—12.7	2 21.5	4 14		10 9		21 23		27 18	

Minima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of minima in 1923 March							
	h m	° ′		d h	d h		d h		d h		d h	
δ Libræ	14 55.6	— 8 07	4.8— 6.2	2 07.9	8 16		15 16		22 15		29 15	
U Coronæ	15 14.1	+32 01	7.6— 8.7	3 10.9	7 17		14 14		21 12		28 10	
TW Draconis	15 32.4	+64 14	7.3— 8.9	2 19.3	2 2		10 12		18 22		27 8	
SS Librae	15 43.4	—15 14	9.3—11.5	0 18.4	7 19		14 23		21 4		29 9	
SW Ophiuchi	16 11.1	— 6 44	9.2—10.0	2 10.7	4 11		11 19		19 3		26 11	
SX Ophiuchi	12.6	— 6 25	10.5—11.2	2 01.5	8 10		16 16		24 22			
R Aræ	31.1	—56 48	6.8— 7.9	4 10.2	7 21		15 22		24 19			
TT Herculis	16 49.9	+17 00	8.9— 9.3	20 18.1			8 4		29 22			
TU Herculis	17 09.8	+30 50	9.5—12	2 06.4	2 7		9 3		22 17		29 12	
U Ophiuchi	11.5	+ 1 19	6.0— 6.7	0 20.1	9 3		17 13		25 22			
α Herculis	13.6	+33 12	4.6— 5.4	2 01.2	4 5		10 8		22 16		28 19	
TX Herculis	15.4	+42 00	8.3— 9.0	1 00.7	3 11		9 15		22 0		28 4	
RV Ophiuchi	29.8	+ 7 19	9. —12	3 16.5	2 5		9 13		24 7		31 17	
SZ Herculis	36.0	+33 01	9.5—10.3	0 19.6	7 15		15 19		23 9			
TX Scorpii	48.6	—34 13	7.5— 8.2	0 22.6	6 12		14 2		19 15		29 4	
UX Herculis	49.7	+16 57	8.8—10.5	1 13.2	4 18		12 11		20 6		28 0	
Z Herculis	53.6	+15 09	7.1— 7.9	3 23.8	8 14		16 13		24 13			
WX Sagittarii	53.6	—17 24	9.2—10.8	2 03.1	2 18		11 7		19 19		28 7	
WY Sagittarii	17 54.9	—23 1	9.5—10.6	4 16.0			10 0		19 7		28 15	
SX Draconis	18 03.0	+58 23	9.3—10.5	5 04.1	6 17		17 1		27 9			
RS Sagittarii	11.0	—34 08	5.9— 6.3	2 10.0	6 7		13 13		20 19		28 1	
V Serpentis	11.1	—15 34	9.5—11.1	3 10.9	6 2		12 23		19 21		26 19	
RZ Scuti	21.1	— 9 15	7.4— 8.3	15 03.2	3 22				19 2			
RZ Draconis	21.8	+58 50	9.5—10.2	0 13.2	5 11		12 16		19 19		26 23	
RX Herculis	26.0	+12 32	7.0— 7.6	0 21.3	7 2		14 5		21 7		28 10	
SX Sagittarii	39.7	—30 36	8.7— 9.8	2 01.8	2 8		10 15		18 22		27 6	
RR Draconis	40.8	+62 34	9.3—13	2 19.9	2 14		11 2		19 14		28 2	
RS Scuti	43.7	—10 21	9.3—10.3	0 15.9	5 0		10 16		23 23		30 14	
β Lyræ	46.4	+33 15	3.4— 4.1	12 21.8			11 4		24 1			
U Scuti	18 48.9	—12 44	9.1— 9.6	0 22.9	5 8		13 0		20 15		28 6	
RX Draconis	19 01.1	+58 35	9.3—10.2	1 21.4	2 1		9 15		17 5		24 19	
RV Lyræ	12.5	+32 15	11. —12.8	3 14.4	3 13		10 17		17 22		25 3	
RS Vulpec.	13.4	+22 16	6.9— 8.0	4 11.4	6 21		15 19		24 18			
U Sagittæ	14.4	+19 26	6.5— 9.0	3 09.1	3 13		10 8		23 21		30 15	
Z Vulpec.	17.5	+25 23	7.3— 8.5	2 10.9	3 8		10 17		18 2		25 11	
TT Lyræ	24.3	+41 30	9.4—11.6	5 05.8	3 1		13 20		19 1		29 13	
UZ Draconis	26.1	+68 44	9.0— 9.8	1 15.1	2 8		8 20		21 21		28 10	
SY Cygni	19 42.7	+32 28	10. —12	6 00.2	5 20		11 20		23 20		29 20	
WW Cygni	20 00.6	+41 18	9.3—13.4	3 07.6	1 17		8 8		21 15		28 6	
SW Cygni	03.8	+46 01	9. —11.7	4 13.8	2 0		10 4		19 7		28 11	
VW Cygni	11.4	+34 12	9.8—11.8	8 10.3	1 16		10 3		18 13		26 23	
RW Capric.	12.2	—17 59	8.8—10.6	3 09.4	4 11		11 5		24 19		31 14	
UW Cygni	19.6	+42 55	10.5—13	3 10.8	6 22		13 19		20 17		27 15	
V Vulpec.	32.3	+26 15	8.2— 9.8	37 19.0								
W Delphini	33.1	+17 56	9.4—12.1	4 19.4	10 3		19 17		29 8			
RR Delphini	38.9	+13 35	10.5—11.8	4 14.4	7 16		16 21		26 2			
Y Cygni	48.1	+34 17	7.1— 7.9	1 12.0	6 4		15 4		24 4			
WZ Cygni	48.3	+38 27	9.9—10.8	0 14.0	1 6		8 20		24 1		31 15	
RR Vulpec.	20 50.5	+27 32	9.6—11.0	5 01.2	6 4		16 6		26 9			
RY Aquarii	14.8	—11 14	8.8—10.4	1 23.2	6 18		14 15		22 12		30 9	
RT Lacertæ	21 57.4	+43 24	9.1—10.5	5 01.7	3 13		13 17		23 20			
UZ Cygni	55.2	+43 52	8.9—11.6	31 07.3					28 9			
RW Lacertæ	22 40.6	+49 08	10.2—11.2	5 04.4	5 12		15 21		21 2		31 11	
VW Pegasi	51.7	+32 41	10.0—10.6	5 06.4	4 20		10 3		20 15		25 22	
Y Piscium	29.3	+ 7 22	9.0—12.0	3 18.3	1 17		9 6		24 7		31 20	
TW Androm.	23 58.2	+32 17	8.6—11.5	4 02.9	2 18		11 0		19 6		27 12	

Maxima of Variable Stars of Short Period.

[Calculated by members of the class in General Astronomy at Carleton College.]

Given to the nearest hour in Greenwich mean time; to obtain Eastern Standard time subtract 5^h; Central Standard time 6^h, etc.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1923 March					
	h m	° ′		d h	d h	d h	d h	d h	d h	d h
SX Cassiop.	0 05.5	+54 20	8.6— 9.2	36 13.7			28 4			
SY Cassiop.	0 09.8	+57 52	9.3— 9.9	4 1.7	1 17	9 21	18 0	26 3		
RR Ceti	1 27.0	+ 0 50	8.3— 9.0	0 13.3	6 4	13 22	21 15	29 9		
RW Cassiop.	1 30.7	+57 15	8.9—11.0	14 19.2	6 17		21 12			
V Arietis	2 09.6	+11 46	8.3— 9.0	0 23.8	2 15	10 13	18 12	26 10		
SU Cassiop.	2 43.0	+68 28	6.5— 7.0	1 22.8	3 15	11 10	19 5	27 0		
RW Camelop.	3 46.2	+58 21	8.2— 9.4	16 00.0	4 7		20 17			
SX Persei	4 10.2	+41 27	10.4—11.2	4 07.0	3 15	12 5	20 19	29 9		
SV Persei	42.8	+42 07	8.8— 9.6	11 03.1	5 3	16 6	27 9			
RX Aurigæ	4 54.5	+39 49	7.2— 8.1	11 15.0		10 6	21 21			
SX Aurigæ	5 04.6	+42 02	8.0— 8.7	1 12.8	4 0	11 16	19 8	27 0		
SY Aurigæ	05.5	+42 41	8.4— 9.5	10 03.3		10 22	21 2	31 0		
Y Aurigæ	21.5	+42 21	8.6— 9.6	3 20.6	7 20	15 13	23 6	31 0		
RZ Gemin.	5 56.6	+22 15	9.1—10.0	5 12.7	4 8	9 21	20 22	26 11		
RS Orionis	6 16.5	+14 44	8.2— 8.9	7 13.6	1 10	8 23	24 3	31 16		
T Monoc.	19.8	+ 7 08	5.7— 6.8	27 00.3		11 7				
RT Aurigæ	23.0	+30 33	5.1— 6.0	3 17.5	2 8	9 19	17 6	24 17		
W Gemin.	29.2	+15 24	6.7— 7.5	7 22.0	6 22	14 20	22 18	30 16		
ζ Gemin.	6 58.2	+20 43	3.7— 4.3	10 03.7	3 21	14 1	24 4			
RU Camelop.	7 10.9	+69 51	8.5— 9.8	22 06.5			20 6			
RR Gemin.	7 15.2	+31 04	10.0—11.5	0 09.5	2 20	10 19	18 17	26 16		
V Carinæ	8 26.7	—59 47	7.4— 8.1	6 16.7	3 17	10 9	23 18	30 11		
T Velorum	8 34.4	—47 01	7.6— 8.5	4 15.3	5 16	14 23	24 5			
V Velorum	9 19.2	—55 32	7.5— 8.2	4 08.9	4 17	13 11	22 4	30 22		
Z Leonis	9 46.4	+27 22	7.9— 9.6	59 00.0						
RR Leonis	10 02.1	+24 29	9.1—10.1	0 10.9	4 4	10 23	17 18	24 13		
SU Draconis	11 32.2	+67 53	8.9— 9.6	0 15.8	6 23	13 13	20 4	26 18		
S Muscae	12 07.4	—69 36	6.4— 7.3	9 15.8	9 17	19 9	29 1			
SW Draconis	12.8	+70 04	8.8— 9.6	0 13.7	6 19	17 20	22 18	30 17		
T Crucis	15.9	—61 44	6.8— 7.6	6 17.6	4 23	11 17	25 4	30 21		
R Crucis	18.1	—61 04	6.8— 7.9	5 19.8	6 2	11 21	23 13	29 9		
S Crucis	12 48.4	—57 53	6.5— 7.6	4 16.6	3 19	8 12	17 21	27 6		
W Virginis	13 20.9	— 2 52	8.7—10.4	17 06.5	6 10		23 16			
SS Hydræ	25.0	—23 08	7.4— 8.1	8 04.8	8 20	17 0	25 5			
RV Urs. Maj.	13 29.4	+54 31	9.2— 9.9	0 11.2	6 4	13 4	20 4	27 5		
ST Virginis	14 22.5	— 0 27	10.3—11.4	0 09.9	6 23	15 4	23 9	31 15		
V Centauri	25.4	—56 27	6.4— 7.8	5 11.9	1 17	12 16	18 4	29 4		
RS Bootis	29.3	+32 11	8.9—10.0	0 09.1	2 7	9 20	17 9	24 23		
R Triang.Austr.	15 10.8	—66 08	6.7— 7.4	3 09.3	2 8	9 3	22 16	29 11		
S Triang.Austr.	15 52.2	—63 29	6.4— 7.4	6 07.8	4 17	11 1	23 16	31 0		
S Normæ	16 10.6	—57 39	6.6— 7.6	9 18.1	5 21	15 15	25 9			
RW Draconis	33.7	+58 03	9.6—10.8	0 10.6	5 9	14 6	23 3	31 23		
RV Scorpii	16 51.8	—33 27	6.7— 7.4	6 01.5	3 19	9 21	22 0	27 1		
X Sagittarii	17 41.3	—27 48	4.4— 5.0	7 00.3	4 5	11 5	18 6	25 6		
Y Ophiuchi	47.3	— 6 07	6.1— 6.5	17 02.9		7 13	24 16			
W Sagittarii	17 58.6	—29 35	4.3— 5.1	7 14.3	4 23	12 14	20 4	27 18		
Y Sagittarii	18 15.5	—18 54	5.4— 6.2	5 18.6	3 19	9 13	21 3	26 21		
U Sagittarii	26.0	—19 12	6.5— 7.3	6 17.9	1 19	8 13	22 1	28 19		
Y Scuti	32.6	— 8 27	8.7— 9.2	10 08.3	8 18	19 2	29 10			
RZ Lyræ	18 39.9	+32 42	9.9—11.2	0 12.3	8 7	14 11	20 14	26 17		
RT Scuti	18 44.1	—10 30	9.1— 9.7	0 11.9	1 12	13 9	19 8	31 5		
κ Pavonis	18 46.6	—67 22	3.8— 5.2	9 02.2	5 16	14 19	23 21			
U Aquilæ	19 24.0	— 7 15	6.2— 6.9	7 00.6	1 13	8 14	22 15	29 16		

Maxima of Variable Stars of Short Period—Continued.

Star	R.A. 1900	Decl. 1900	Magnitude	Approx. Period	Greenwich mean times of maxima in 1923 March							
	h m	° ′		d h	d h	d h	d h	d h	d h	d h	d h	d h
XZ Cygni	19 30.4	+56 10	8.6— 9.3	0 11.2	4 21	11 21	18 21	25 21				
U Vulpec.	32.2	+20 07	6.5— 7.6	7 23.5	11 0	18 0	25 23					
SU Cygni	40.8	+29 01	6.2— 7.0	3 20.3	7 3	14 20	22 12	30 5				
η Aquilæ	47.4	+ 0 45	3.7— 4.5	7 04.2	2 23	10 3	24 11	31 15				
S Sagittæ	51.5	+16 22	5.6— 6.4	8 09.2	4 11	12 20	21 5	29 14				
X Vulpec.	19 53.3	+26 17	9.5—10.5	6 07.7	7 2	13 9	19 17	26 1				
X Cygni	20 39.5	+35 14	6.0— 7.0	16 09.3		16 15						
T Vulpec.	47.2	+27 52	5.5— 6.1	4 10.5	4 21	13 18	22 15	31 12				
WY Cygni	52.3	+30 03	9.6—10.4	0 13.5	4 10	11 4	24 15	31 8				
RV Capric.	55.9	—15 37	9.2—10.1	0 10.7	4 23	11 16	25 2	31 19				
TX Cygni	20 56.4	+42 12	8.5— 9.7	14 17.4	3 22		18 15					
VY Cygni	21 00.4	+39 34	8.8— 9.5	7 20.6	4 14	12 11	20 7	28 4				
SW Aquarii	10.2	— 0 20	9.9—10.8	0 11.0	5 17	12 15	19 12	26 9				
VZ Cygni	21 47.7	+42 40	8.2— 9.2	4 20.7	3 6	12 23	17 20	27 14				
Y Lacertæ	22 05.2	+50 33	9.1— 9.6	4 07.8		10 16	19 7	27 23				
δ Cephei	25.5	+57 54	3.7— 4.6	5 08.8	1 21	12 14	17 23	28 17				
Z Lacertæ	36.9	+56 18	8.2— 9.0	10 21.1	6 10	17 7	28 5					
RR Lacertæ	37.5	+55 55	8.5— 9.2	6 10.1	1 7	7 16	20 12	26 22				
V Lacertæ	44.5	+55 48	8.5— 9.5	4 23.6	5 0	14 23	19 22	29 22				
X Lacertæ	22 45.0	+55 54	8.2— 8.6	5 10.7	1 0	11 21	17 8	28 5				
SW Cassiop.	23 03.7	+58 11	9.2— 9.7	5 10.6	4 3	15 0	20 11	31 8				
RS Cassiop.	32.6	+61 52	9.0—11.0	6 07.1	5 15	11 22	24 13	30 20				
RY Cassiop.	47.2	+58 11	9.3—11.8	12 03.4	4 1	16 4	28 7					
V Cephei	23 51.7	+82 38	6.0— 7.0	0 23.9	7 5	14 5	21 4	28 4				

Monthly Report of the American Association of Variable Star Observers, Nov. 20-Dec. 20, 1922.

Mr. T. S. Jacobsen of Stanford University has gone to Lick Observatory as a Fellow. Professor S. D. Townley, also of Stanford University, is spending a half year at Harvard Observatory working on Variable Stars. Mr. S. L. Rhorer of Atlanta, Ga., plans to erect a five-inch refractor at Miami, Fla., for his use during the winter months and he hopes to find someone there who will be able to use it for the Association work during the rest of the year.

Mr. S. C. Hunter, of New Rochelle, N. Y., has gone on a world tour and the Secretary, Mr. Olcott, will spend the next two months in Florida. Professor Anne S. Young lectured before the Brooklyn Institute at New York on January 19 on the subject of Variable Stars.

Association telescopes have recently been loaned to Mr. L. E. Cunningham of Wiscasset, Me., and to Mr. Roy Marshall of Lebanon, Ohio. The chairman of the Telescope Committee calls attention to the need for borrowers of telescopes to keep the instruments in reasonable use, since they are too valuable to be allowed to remain idle when so many worthy observers are seeking the loan of such instruments.

Mira, *o* Ceti, *021403*, will doubtless reach maximum before the end of the present opposition, and all members are urged to observe it carefully, especially since it will soon reach naked eye visibility.

The Recording Secretary will be in the East for the next few months so members are requested to send their A. A. V. S. O. reports, together with their H. C. O. reports, each month direct to Harvard Observatory.

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922.

November 0 = J. D. 2423359 December 0 = J. D. 2423389

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
000339 V SCULPTORIS—												
	3343.0	<14.0	Bl.									
001032 S SCULPTORIS—												
	3343.0	9.1	Bl,	3378.9	7.7	Kd,	3381.9	7.7	Kd,	3401.5	6.9	Pt.
001046 X ANDROMEDAE—												
	3374.7	9.1	Lv,	3387.6	9.5	B,	3401.6	9.9	Hu,	3403.7	10.1	B.
	3406.6	10.4	Lv.									
001620 T CETI—												
	3323.0	6.4	Kd,	3336.0	6.5	Kd,	3339.0	6.7	Kd,	3343.1	6.6	Kd,
	3347.0	6.7	Kd,	3350.0	6.5	Kd,	3356.0	6.4	Kd,	3362.0	6.0	Kd,
	3365.0	6.2	Kd,	3366.0	6.2	Kd,	3369.2	6.0	L,	3369.3	5.7	An,
	3369.9	6.1	Kd,	3372.0	6.1	Kd,	3376.3	5.7	An.	3377.0	5.9	Kd,
	3379.3	5.4	L,	3381.9	6.0	Kd.						
001726 T ANDROMEDAE—												
	3327.1	9.3	Ch,	3341.1	9.8	Ch,	3374.7	12.3	Lv,	3379.7	<12.5	Br,
	3381.7	12.7	Lv,	3387.6	12.1	B,	3391.7	12.9	Lv,	3401.5	13.0	Pt,
	3404.6	13.0	Lv,	3404.6	13.1	B.						
001755 T CASSIOPEIAE—												
	3364.5	9.7	Gi,	3369.3	11.6	L,	3375.6	10.2	B,	3389.5	10.8	Gi,
	3393.6	10.9	B,	3401.5	12.0	Pt.						
001838 R ANDROMEDAE—												
	3376.9	14.2	Wf,	3401.5	13.2	Pt.						
001862 S TUCANAE—												
	3345.2	8.4	Bl.									
001909 S CETI—												
	3340.1	10.0	Ch,	3356.1	9.4	Ch,	3369.3	9.1	L,	3378.5	8.4	O,
	3379.3	8.7	L,	3381.7	8.0	Sg,	3401.5	7.8	Pt.			
002546 T PHOENICIS—												
	3343.0	9.1	Bl.									
002833 W SCULPTORIS—												
	3343.0	13.0	Bl.									
003179 Y CEPHEI—												
	3379.7	<12.4	Br,	3404.6	12.7	B.						
004047 U CASSIOPEIAE—												
	3361.7	12.4	Lv,	3374.7	12.8	Lv,	3375.6	13.0	B,	3376.9	13.7	Wf,
	3381.7	13.2	Lv,	3391.7	<12.7	Lv,	3401.5	13.8	Pt.			
004132a RW ANDROMEDAE—												
	3376.9	11.5	Wf,	3379.7	11.7	Br.						
004435 V ANDROMEDAE—												
	3374.7	10.2	Lv,	3379.7	10.4	Br,	3381.7	10.1	Lv,	3393.6	9.8	Lv,
	3397.7	9.8	Lv,	3404.7	9.6	Lv.						
004435 X SCULPTORIS—												
	3345.2	11.1	Bl.									
004533 RR ANDROMEDAE—												
	3376.9	9.9	Wf,	3379.7	10.4	Br,	3392.6	9.6	B,	3403.7	9.4	B.
004746a RV CASSIOPEIAE—												
	3369.3	12.8	L,	3377.0	11.5	Wf,	3380.6	11.2	Br,	3401.5	9.1	Pt.
004958 W CASSIOPEIAE—												
	3364.6	10.6	Gi,	3376.6	10.5	B,	3380.6	10.9	Br,	3383.4	10.3	Gi,
	3393.6	9.8	B,	3401.5	10.3	Pt.						
005475 U TUCANAE—												
	3345.2	11.2	Bl.									
010102 Z CETI—												
	3391.6	11.1	B,	3401.5	12.1	Pt.						
010630 U SCULPTORIS—												
	3345.2	14.5	Bl.									
010940 U ANDROMEDAE—												
	3376.9	13.8	Wf,	3404.6	<13.6	B.						

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
011041 UZ ANDROMEDAE—												
	3377.0	<14.2	Wf.									
011208 S PISCIUM—												
	3378.6	12.9	B,	3398.5	13.3	Y,	3404.6	13.7	B.			
011272 S CASSIOPEIAE—												
	3376.9	14.8	Wf,	3381.8	13.9	Lv,	3397.7	13.1	Lv.	3401.5	14.4	Pt.
011712 U PISCIUM—												
	3380.7	<13.0	Br,	3401.5	13.3	Pt.						
012350 RZ PERSEI—												
	3380.7	12.7	Br,	3398.5	11.2	Y.						
012502 R PISCIUM—												
	3398.5	<13.5	Y.									
013238 RU ANDROMEDAE—												
	3341.1	10.9	Ch,	3376.6	10.4	B,	3377.0	10.7	Wf.	3393.6	10.6	B,
	3401.5	11.3	Pt.									
013338 Y ANDROMEDAE—												
	3341.1	<11.5	Ch,	3401.5	11.6	Pt.						
014958 X CASSIOPEIAE—												
	3398.5	12.3	Y,	3401.5	12.6	Pt,	3403.7	11.6	B.			
015354 U PERSEI—												
	3391.6	8.3	B,	3401.5	7.8	Pt.						
021024 R ARIETIS—												
	3364.5	8.1	Gi,	3369.3	7.9	L,	3378.6	8.0	B,	3383.8	8.9	Jb,
	3389.5	8.2	Gi,	3401.5	9.0	Pt,	3404.6	9.1	B.			
021143a W ANDROMEDAE—												
	3376.3	8.1	Gi,	3385.6	8.5	Br,	3389.5	8.7	Gi,	3392.6	8.2	B,
	3401.5	9.0	Pt.									
021258 T PERSEI—												
	3399.6	8.9	Hu.									
021281 Z CEPHEI—												
	3377.0	14.0	Wf,	3404.7	<13.6	B.						
021403 o CETI—												
	3332.5	8.5	Bp,	3347.2	8.6	Ch,	3369.3	8.4	L,	3369.7	8.1	Jb,
	3378.5	8.1	O,	3379.6	8.1	L,	3381.7	8.0	Sg,	3383.6	8.3	O,
	3383.8	7.9	Jb,	3394.5	8.0	O,	3399.6	7.9	Hu,	3405.5	7.7	O.
021558 S PERSEI—												
	3385.7	10.5	Br,	3393.6	10.2	B,	3399.6	10.0	Hu,	3401.5	10 5	Pt.
022000 R CETI—												
	3379.0	8.4	Kd.									
022150 RR PERSEI—												
	3385.7	<13.0	Br.									
022426 R FORNACIS—												
	3345.2	9.3	Bl.									
022813 U CETI—												
	3348.2	7.6	Ch,	3356.2	7.2	Ch,	3377.1	8.1	Kd,	3378.5	7.5	O,
	3379.1	8.1	Kd,	3401.5	8.4	Pt,	3408.6	8.6	Y.			
022980 RR CEPHEI—												
	3376.9	13.7	Wf.									
023133 R TRIANGULI—												
	3341.0	7.0	Kd,	3343.0	7.0	Kd,	3344.1	7.0	Kd,	3347.1	7.0	Kd,
	3349.0	7.1	Kd,	3352.1	7.1	Kd,	3354.1	7.2	Kd,	3366.0	7.3	Kd,
	3369.9	7.2	Kd,	3377.1	7.3	Kd,	3381.9	7.3	Kd,	3392.5	7.8	B,
	3399.5	8.2	M,	3399.6	8.2	Hu,	3401.5	8.1	Pt.			
024217 T ARIETIS—												
	3352.0	8.9	Kd,	3379.0	9.2	Kd.						
024356 W PERSEI—												
	3302.6	10.7	Ya,	3383.6	10.3	Jb,	3389.7	11.3	Br,	3391.6	10.0	B,
	3394.5	10.6	O,	3399.5	10.7	M,	3399.6	10.0	Hu,	3401.5	11.4	Pt.
	3404.6	10.4	B.									

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
025050 R HOROLOGII—												
	3345.2	8.4	Bl.									
025751 T HOROLOGII—												
	3345.2	12.2	Bl.									
030514 U ARIETIS—												
	3381.4	<14.2	Gi,	3398.5	<13.1	Y.						
031401 X CETI—												
	3369.3	12.2	L,	3376.6	12.1	B,	3401.5	10.1	Pt.			
032043 Y PERSEI—												
	3376.6	9.8	B,	3393.6	9.4	B,	3399.5	9.4	M,	3399.6	8.5	Hu,
	3401.5	9.5	Pt.									
032335 R PERSEI—												
	3364.5	10.9	Gi,	3376.6	12.3	B,	3380.4	12 3	Gi,	3401.5	12.1	Pt.
042209 R TAURI—												
	3376.7	12.1	B,	3398.6	12.7	B.						
042215 W TAURI—												
	3369.8	10.0	Jb,	3376.6	10.4	B,	3381.7	11.1	Pt,	3383.8	10.1	Jb,
	3393.6	10.8	B,	3399.6	10.8	Hu,	3402.5	11.6	O.			
042309 S TAURI—												
	3398.6	<13.0	B.									
043065 T CAMELOPARDALIS—												
	3369.3	12.7	L,	3381.7	12.5	Pt.						
043208 RX TAURI—												
	3376.7	13.3	B,	3398.6	<13.3	B.						
043263 R RETICULI—												
	3345.2	8.2	Bl.									
043274 X CAMELOPARDALIS—												
	3380.6	8.7	Y,	3381.7	8.0	Pt,	3387.6	8.1	B,	3392.6	8.7	M,
	3396.7	8.2	B.									
043562 R DORADUS—												
	3345.2	5.8	Bl.									
043738 R CAELI—												
	3345.2	14.0	Bl.									
044617 V TAURI—												
	3376.7	10.2	B,	3381.7	10.2	Pt,	3393.6	9.7	B.			
045307 R ORIONIS—												
	3376.5	11.1	Gi,	3403.6	11.5	B,	3408.6	12.0	Y.			
045514 R LEPORIS—												
	3326.3	8.0	Ch,	3347.2	8.5	Ch,	3373.6	8.3	L,	3376.7	9.1	Ct,
	3381.7	8.0	Pt.									
050003 V ORIONIS—												
	3381.6	11.6	O,	3381.7	11.8	Pt,	3398.6	12.6	B,	3408.6	12.7	Y.
050022 T LEPORIS—												
	3345.2	10.9	Bl,	3381.7	11.4	Pt.						
050848 S PICTORIS—												
	3345.2	8.2	Bl.									
050953 R AURIGAE—												
	3381.7	7.4	Pt,	3386.7	8.3	Lv,	3387.6	7.2	B,	3392.6	8.0	M.
051247 T PICTORIS—												
	3345.2	13.5	Bl.									
051533 T COLUMBAE—												
	3345.2	12.1	Bl.									
052034 S AURIGAE—												
	3378.3	9.1	L,	3381.7	8.6	Pt,	3387.7	8.8	B,	3396.7	8.7	B.
052036 W AURIGAE—												
	3376.5	14.1	Gi,	3402.6	11.8	B.						
052404 S ORIONIS—												
	3369.8	9.1	Jb,	3381.7	10.0	Pt,	3383.8	9.6	Jb,	3391.7	9 5	B,
	3399.6	8.9	Hu.	3399.6	10.2	O,	3401.6	10.4	Pt.			

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
053005a T ORIONIS—												
	3373.6	9.7	L,	3381.7	10.2	Pt,	3383.8	10.0	Jb,	3399.5	9.9	Pt,
	3399.6	10.0	Hu,	3398.7	10.7	B,	3401.6	11.0	Pt,	3407.6	11.1	Pt.
053068 S CAMELOPARDALIS—												
	3369.7	8.8	Jb,	3381.7	8.5	Pt,	3383.8	8.8	Jb,	3392.6	8.6	M.
053326 RR TAURI—												
	3398.7	12.0	B.									
053531 U AURIGAE—												
	3381.7	13.0	Pt,	3384.9	<12.8	Br,	3398.5	<12.7	Y,	3402.6	13.0	B.
054319 SU TAURI—												
	3326.3	9.5	Ch,	3347.2	9.6	Ch,	3369.8	9.3	Jb,	3373.6	9.6	L,
	3376.9	9.4	Wf,	3380.7	9.8	Br,	3381.7	9.5	Pt,	3382.7	9.6	Pt,
	3383.8	9.6	Jb,	3383.9	9.8	Pt,	3384.7	9.5	Pt,	3384.8	9.5	Br,
	3387.9	9.6	Pt,	3394.9	9.5	Pt,	3396.6	9.5	B,	3397.5	9.5	Pt,
	3399.5	9.4	Pt,	3399.6	9.5	Hu,	3401.5	9.6	Pt,	3404.5	9.6	Pt.
	3406.5	9.5	Pt,	3407.6	9.4	Pt.						
054331 S COLUMBAE—												
	3345.2	10.7	Bl.									
054615a Z TAURI—												
	3384.7	<13.1	Br.									
054615c RU TAURI—												
	3384.9	<13.1	Br.									
054629 R COLUMBAE—												
	3345.2	9.8	Bl.									
054920a U ORIONIS—												
	3369.8	8.8	Jb,	3376.7	9.2	Ct,	3381.7	8.4	Pt,	3381.8	9.2	Lv,
	3383.8	9.1	Jb,	3387.7	8.6	B,	3392.6	9.7	M,	3396.7	8.6	B,
	3399.6	9.5	Hu,	3403.6	9.7	Ct,	3404.7	9.7	Lv,	3405.7	9.6	Ct,
054920b UW ORIONIS—												
	3381.7	10.9	Lv,	3404.7	10.7	Lv.						
054974 V CAMELOPARDALIS—												
	3376.5	<14.0	Gi,	3376.9	14.2	Wf,	3402.5	<13.0	Y			
055353 Z AURIGAE—												
	3381.7	9.6	Pt,	3389.7	9.4	Br,	3391.6	9.7	B,	3402.6	9.9	B,
055686 R OCTANTIS—												
	3345.2	9.4	Bl.									
060450 X AURIGAE—												
	3381.7	12.2	Pt,	3384.9	11.5	Br,	3402.6	9.8	B.			
060547 SS AURIGAE—												
	3326.3	11.0	Ch,	3360.4	<13.8	Gi,	3364.4	<13.3	Gi,	3367.3	11.1	L,
	3369.2	10.8	L,	3369.7	10.6	Jb,	3373.6	11.0	L,	3376.4	12.1	Gi,
	3376.9	12.6	Wf,	3378.3	13.2	L,	3378.5	<11.0	O,	3379.6	<10.8	Jb,
	3380.4	<13.9	Gi,	3380.6	<13.3	Y,	3380.7	<12.4	Br,	3381.4	<13.9	Gi,
	3381.6	<12.6	O,	3381.7	<12.6	Pt,	3382.4	<13.9	Gi,	3382.7	<12.6	Pt,
	3383.4	<13.9	Gi,	3383.5	<12.6	Pt,	3383.6	11.7	O,	3383.8	<11.6	Jb,
	3384.4	<13.9	Gi,	3384.7	<12.6	Pt,	3384.8	<12.4	Br,	3387.9	<12.6	Pt,
	3389.4	<13.8	Gi,	3390.5	<11.0	Pt,	3395.5	<12.6	Pt,	3396.6	<13.3	B,
	3397.5	<12.6	Pt,	3398.5	<13.0	Y,	3398.5	<12.6	Pt,	3399.5	<12.6	Pt,
	3399.6	<12.4	M,	3400.5	<12.6	Pt,	3401.6	11.8	Pt,	3402.5	11.5	O,
	3402.5	11.4	Y,	3404.5	11.8	Pt,	3406.5	13.5	Pt,	3407.5	<13.0	Pt,
	3408.6	12.4	Y.									
061647 V AURIGAE—												
	3391.7	9.9	B.									
061702 V MONOCEROTIS—												
	3381.7	12.8	Pt.									
063159 U LYNCIS—												
	3381.6	10.4	Y,	3402.6	11.1	Y.						
063308 R MONOCEROTIS—												
	3381.7	11.0	Pt,	3384.9	11.6	Br,	3403.6	11.4	B.			

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
063558 S LYNCIS—												
	3381.7	13.3	Pt.									
064030 X GEMINORUM—												
	3376.5	11.2	Gi,	3389.4	10.6	Gi.						
064707 W MONOCEROTIS—												
	3381.7	11.0	Pt,	3384.9	11.2	Br.						
065111 Y MONOCEROTIS—												
	3381.7	10.8	Pt,	3381.8	10.9	Lv.	3386.8	11.1	Lv,	3402.6	11.7	Y,
	3403.6	11.9	B.									
065208 X MONOCEROTIS—												
	3373.7	8.9	L.									
065355 R LYNCIS—												
	3380.4	12.7	Gi,	3381.6	13.0	Y.	3402.6	13.5	Y.			
070109 V CANIS MINORIS—												
	3384.9	10.0	Br.									
070122a R GEMINORUM—												
	3381.7	6.8	Pt,	3386.7	6.7	Lv.	3399.6	7.2	O,	3399.6	7.5	Hu.
070122b Z GEMINORUM—												
	3381.7	12.4	Pt,	3386.8	12.2	Lv.						
070122c TW GEMINORUM—												
	3386.8	8.0	Lv.									
070310 R CANIS MINORIS—												
	3373.7	9.2	L.									
071201 RR MONOCEROTIS—												
	3385.0	11.5	Br.									
071713 V GEMINORUM—												
	3381.7	13.5	Pt.									
072708 S CANIS MINORIS—												
	3373.7	12.6	L,	3381.7	13.2	Pt.						
072811 T CANIS MINORIS—												
	3381.7	9.6	Pt.									
073173 S VOLANTIS—												
	3345.2	9.9	Bl.									
073508 U CANIS MINORIS—												
	3373.7	9.3	L,	3380.6	9.4	Y.	3381.7	9.3	Pt.			
073723 S GEMINORUM—												
	3381.7	8.9	Pt.									
074241 W PUPPIS—												
	3345.2	12.1	Bl.									
074323 T GEMINORUM—												
	3381.7	8.3	Pt.									
074922 U GEMINORUM—												
	3355.3	<11.4	Ch,	3360.4	<12.7	Gi,	3364.4	<12.8	Gi,	3373.6	<13.7	L,
	3376.5	14.0	Gi,	3376.9	14.0	Wf,	3380.4	13.9	Gi,	3380.6	<13.3	Y.
	3381.5	14.0	Gi,	3381.7	<13.3	Pt.	3382.4	13.9	Gi.	3382.7	<13.3	Pt,
	3383.5	14.0	Gi,	3383.6	<11.7	O,	3383.8	<12.4	Jb.	3383.9	<13.3	Pt,
	3384.5	14.0	Gi,	3384.7	<12.4	Pt.	3384.8	<13.0	Br.	3387.9	<13.3	Pt,
	3389.5	<13.3	Gi,	3401.6	<13.3	Pt.	3402.6	<13.3	Y.	3404.6	<13.3	Pt.
	3406.5	<13.3	Pt.	3407.6	<12.4	Pt.	3408.6	<13.3	Y.			
081112 R CANCRI—												
	3355.3	11.4	Ch.	3373.6	10.4	L,	3381.7	10.0	Pt,	3385.0	10.5	Br.
081617 V CANCRI—												
	3355.3	8.0	Ch.	3376.6	8.0	Gi.	3383.9	8.4	Pt.	3385.0	8.8	Br.
082405 RT HYDRAE—												
	3373.7	7.4	L.	3383.9	7.7	Pt.						
082476 R CHAMELEONIS—												
	3345.3	10.2	Bl.									
083019 U CANCRI—												
	3376.9	14.0	Wf.									

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
083350 X URSAE MAJORIS—												
	3383.9	13.4	Pt.									
084803 S HYDRAE—												
	3383.9	8.7	Pt.									
085008 **T HYDRAE—**												
	3373.7	10.6	L.	3383.9	10.6	Pt.						
085120 T CANCRI—												
	3373.6	9.6	L.	3383.9	8.5	Pt.						
090024 **S PYXIDIS—**												
	3383.9	10.8	Pt.									
090425 W CANCRI—												
	3373.7	12.0	L.	3376.9	11.2	Wf.						
091868 **RW CARINAE—**												
	3345.3	8.9	Bl.									
092551 **Y VELAE—**												
	3345.3	13.7	Bl.									
092962 **R CARINAE—**												
	3345.3	9.2	Bl.									
093014 **X HYDRAE—**												
	3359.4	9.2	Ch.	3383.9	9.7	Pt.						
093178 Y DRACONIS—												
	3380.7	12.2	Y.	3402.5	12.9	Y.						
093934 R LEONIS MINORIS—												
	3373.7	12.0	L.	3383.9	11.7	Pt.						
094211 R LEONIS—												
	3359.4	6.5	Ch.	3383.9	6.3	Pt.						
094622 **Y HYDRAE—**												
	3383.9	6.5	Pt.									
094953 **Z VELAE—**												
	3345.3	10.6	Bl.									
095421 V LEONIS—												
	3359.4	11.0	Ch.	3376.9	11.8	Wf.	3383.9	11.5	Pt.			
095563 **RV CARINAE—**												
	3345.3	<12.5	Bl.									
100661 **S CARINAE—**												
	3337.9	8.4	Bl.	3348.9	6.9	Bl.						
101058 **Z CARINAE—**												
	3345.3	11.5	Bl.									
101153 **W VELAE—**												
	3345.3	10.7	Bl.									
103212 **U HYDRAE—**												
	3358.3	5.9	Kd.	3362.3	5.8	Kd.	3365.3	5.9	Kd.	3373.7	5.1	L.
	3382.3	6.1	Kd.									
103769 R URSAE MAJORIS—												
	3359.4	10.8	Ch.	3383.9	12.1	Pt.						
104620 **V HYDRAE—**												
	3359.5	9.6	Ch.	3373.7	9.4	L.	3383.9	8.4	Pt.			
111561 **RY CARINAE—**												
	3337.9	<12.1	Bl.									
111661 **RS CENTAURI—**												
	3337.9	<12.1	Bl.									
115058 **W CENTAURI—**												
	3337.9	<12.6	Bl.									
115919 R COMAE BERENICES—												
	3376.9	13.6	Wf.									
121418 **R CORVI—**												
	3387.9	11.0	Pt.									
122001 SS VIRGINIS—												
	3373.7	5.9	L.	3381.3	7.2	Kd.	3382.3	7.2	Kd.			

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.Obs.	J.D.	Est.Obs.	J.D.	Est.Obs.	J.D.	Est.Obs.
122532 T CANUM VENATICORUM—								
	3387.9	10.6 Pt.						
122803 Y VIRGINIS—								
	3373.7	12.0 L.						
122854 U CENTAURI—								
	3337.9<11.7 Bl.							
123160 T URSAE MAJORIS—								
	3359.4	9.3 Ch.	3387.9	11.6 Pt.				
123307 R VIRGINIS—								
	3373.7	7.0 L,	3387.9	7.5 Pt.				
123961 S URSAE MAJORIS—								
	3359.4	7.6 Ch.	3364.2	7.4 L.	3376.6	7.7 Ct.	3379.3	8.5 L,
	3379.6	7.3 Jd,	3387.9	8.0 Pt.				
124606 U VIRGINIS—								
	3387.9	11.4 Pt.						
131283 U OCTANTIS—								
	3337.9	11.6 Bl.	3348.9	10.4 Bl.				
132422 R HYDRAE—								
	3387.9	6.9 Pt.						
132706 S VIRGINIS—								
	3387.9	12.3 Pt.						
133155 RV CENTAURI—								
	3342.9	9.3 Bl,	3348.9	9.5 Bl.				
133633 T CENTAURI—								
	3342.9	6.2 Bl.						
134236 RT CENTAURI—								
	3342.9	11.7 Bl.						
134440 R CANUM VENATICVRUM—								
	3387.9	10.4 Pt.						
134536 RX CENTAURI—								
	3342.9	11.1 Bl.						
134677 T APUS—								
	3337.9	10.8 Bl.	3342.9	10.2 Bl.	3348.9	10.1 Bl.		
135908 RR VIRGINIS—								
	3387.9	12.4 Pt.						
140528 RU HYDRAE—								
	3342.9<12.0 Bl.							
140959 R CENTAURI—								
	3338.0	11.1 Bl.	3348.9	10.9 Bl.				
141567 U URSAE MINORIS—								
	3340.1	11.8 Ch.	3387.9	11.8 Pt.				
141954 S BOOTIS—								
	3360.3	11.8 Gi,	3378.2	12.5 L.	3379.2	12.4 Gi.		
142539 V BOOTIS—								
	3367.3	7.7 L.	3387.9	7.5 Pt.				
142584 R CAMELOPARDALIS—								
	3376.6	13.5 Gi.						
143227 R BOOTIS—								
	3387.9	11.8 Pt.						
144918 U BOOTIS—								
	3360.2	11.4 Gi.						
145254 Y LUPI—								
	3338.0<12.8 Bl.							
145971 S APUS—								
	3338.0	9.8 Bl.	3348.9	10.2 Bl.				
151731 S CORONAE BOREALIS—								
	3387.9	6.9 Bl.						
151822 RS LIBRAE—								
	3342.9	9.9 Bl.						

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
152849 R NORMAE—												
	3338.0	9.0	Bl.	3348.9	8.9	Bl.						
153020 X LIBRAE—												
	3342.9	11.1	Bl.									
153378 S URSAE MINORIS—												
	3387.9	11.5	Bl.									
153620 U LIBRAE—												
	3342.9	<12.0	Bl.									
154020 Z LIBRAE—												
	3342.9	<12.0	Bl.									
154428 R CORONAE BOREALIS—												
	3319.7	6.2	To,	3321.9	6.1	Kd,	3335.9	5.9	Kd,	3337.9	6.0	Kd.
	3338.1	6.2	Ch,	3342.9	5.9	Kd,	3349.9	6.0	Kd.	3353.9	6.0	Kd,
	3364.2	5.5	An,	3364.2	6.2	L,	3367.2	6.1	L.	3369.2	6.5	An.
	3369.9	6.3	Kd,	3378.2	6.3	L,	3381.5	6.2	Pt,	3383.5	6.1	Pt,
	3387.5	6.2	Pt,	3388.5	6.3	Pt.	3392.5	6.2	Pt.	3394.5	6.1	Pt,
	3401.1	6.4	Br.									
154639 V CORONAE BOREALIS—												
	3387.9	7.0	Pt.									
160021 Z SCORPII—												
	3342.9	9.9	Bl.	3348.9	9.8	Bl.						
160118 R HERCULIS—												
	3339.1	<11.0	Ch.									
160221a X SCORPII—												
	3343.0	11.4	Bl,	3348.9	11.5	Bl.						
160519 W SCORPII—												
	3343.0	<12.0	Bl.									
160625a RU HERCULIS—												
	3378.2	11.4	L,	3387.9	11.7	Pt.						
160625b SX HERCULIS—												
	3364.2	8.9	L,	3378.2	9.1	L,	3387.9	8.1	Pt,	3394.9	8.1	Pt.
161122a R SCORPII—												
	3342.9	<13.0	Bl.									
161122b S SCORPII—												
	3342.9	12.0	Bl,	3348.9	11.9	Bl.						
162119 U HERCULIS—												
	3360.2	12.0	Gi,	3376.2	11.8	Gi.						
162815 T OPHIUCHI—												
	3343.0	<12.0	Bl.									
162816 S OPHIUCHI—												
	3343.0	9.9	Bl,	3348.9	9.9	Bl.						
163266 R DRACONIS—												
	3340.1	11.0	Ch.	3347.0	10.9	Ch.	3379.6	8.5	Jd.			
164715 S HERCULIS—												
	3339.1	8.0	Ch,	3348.1	7.8	Ch.	3367.3	7.9	Gi.	3384.2	8.0	Gi.
164844 RS SCORPII—												
	3338.0	8.1	Bl,	3348.9	8.6	Bl.						
165030 RR SCORPII—												
	3338.0	7.0	Bl,	3348.9	6.8	Bl.						
165631 RV HERCULIS—												
	3399.5	11.5	Pt.									
165636 RT SCORPII—												
	3338.0	<13.5	Bl.									
170215 R OPHIUCHI—												
	3338.1	9.4	Ch,	3350.0	8.4	Ch.						
170627 RT HERCULIS—												
	3377.6	10.0	Wf,	3399.5	10.8	Pt.						
170833 RW SCORPII—												
	3338.0	<12.5	Bl.									

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
171401 Z OPHIUCHI—												
	3320.7	11.5	To,	3369.3	9.4	Gi,	3384.2	8.9	Gi.			
171723 RS HERCULIS—												
	3399.5	8.5	Pt.									
172486 S OCTANTIS—												
	3338.0	12.1	Bl,	3349.0	10.1	Bl.						
172809 RU OPHIUCHI—												
	3319.8	<12.2	To.									
173543 RU SCORPII—												
	3338.0	9.0	Bl,	3348.9	8.7	Bl.						
174162 W PAVONIS—												
	3338.0	13.5	Bl.									
174135 SV SCORPII—												
	3338.0	<12.5	Bl.									
175111 RT OPHIUCHI—												
	3319.8	<12.2	To.									
175458a T DRACONIS—												
	3358.2	10.5	Ch,	3364.3	10.3	Gi,	3370.3	11.5	Bp.			
175458b UY DRACONIS—												
	3358.2	10.5	Ch.									
175519 RY HERCULIS—												
	3301.7	9.2	To,	3319.8	9.1	To,	3323.7	9.0	To,	3338.1	9.6	Ch,
	3344.7	10.1	To,	3348.2	9.9	Ch,	3352.7	10.3	To,	3369.7	10.8	Jb,
	3372.6	11.4	To,	3382.6	<11.6	To,	3399.5	13.2	Pt.			
180531 T HERCULIS—												
	3319.8	9.2	To,	3323.7	9.2	To,	3332.4	9.3	Bp,	3338.1	8.6	Ch,
	3344.7	8.3	To,	3348.1	8.2	Ch,	3352.7	7.8	To,	3361.7	7.5	To,
	3367.3	8.1	L,	3369.7	7.7	Jb,	3372.7	8.0	To,	3378.3	8.4	L,
	3379.6	8.5	Ct,	3382.6	8.4	To,	3385.7	8.8	Ct,	3386.7	8.9	Ct,
	3392.5	9.2	M.	3399.5	9.5	Pt.						
180666 X DRACONIS—												
	3399.5	14.5	Pt.									
180911 NOVA OPHIUCHI #4—												
	3382.3	12.8	Gi.									
181031 TV HERCULIS—												
	3367.3	10.2	L,	3379.3	10.1	L.						
181103 RY OPHIUCHI—												
	3364.2	9.7	Gi,	3379.2	8.1	Gi,	3399.5	8.0	Pt.			
181136 W LYRAE—												
	3377.6	12.1	Wf,	3378.3	11.6	L,	3391.5	10.0	B,	3392.5	10.2	M,
	3397.5	9.3	Pt,	3398.5	9.3	Y.						
182133 RV SAGITTARII—												
	3338.0	11.6	Bl.									
182224 SV HERCULIS—												
	3378.2	13.5	L,	3397.5	13.6	Pt.						
183149 SV DRACONIS—												
	3381.5	12.8	Y,	3398.5	<13.0	Y.						
183225 RZ HERCULIS—												
	3381.5	13.0	Y,	3398.5	12.2	Y.						
183308 X OPHIUCHI—												
	3367.3	8.7	L,	3379.3	8.5	L,	3399.5	8.0	Pt.			
184205 R SCUTI—												
	3321.9	6.6	Kd,	3322.9	6.6	Kd,	3335.9	5.9	Kd,	3337.9	5.8	Kd,
	3340.9	5.8	Kd,	3342.9	5.9	Kd,	3348.0	5.8	Kd,	3349.9	5.4	Kd,
	3352.1	5.7	Ch,	3353.9	5.4	Kd,	3360.9	5.4	Kd,	3364.2	5.1	L,
	3364.2	5.5	An,	3367.2	5.3	An,	3369.2	5.2	An,	3369.6	5.6	Jb,
	3369.9	5.5	Kd,	3373.2	5.6	An,	3377.2	5.9	An,	3377.9	5.9	Kd,
	3378.2	5.3	L,	3379.3	5.8	An,	3379.6	5.7	Ct,	3381.5	5.8	Pt,
	3381.9	6.1	Kd,	3382.6	5.7	Ct,	3383.5	5.8	Pt,	3386.6	5.9	Ct,
	3387.5	6.0	Pt,	3388.5	5.8	Pt,	3389.6	5.7	Ct,	3390.5	5.9	Pt,

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
184305 R SCUTI—Continued												
	3392.5	5.7	Pt,	3392.5	5.0	M,	3394.5	5.7	Pt,	3397.5	6.0	Pt.
	3398.5	5.8	Pt,	3399.5	5.8	Pt,	3400.5	5.6	Pt,	3400.6	5.7	Ct,
	3401.5	5.6	Pt,	3403.6	5.6	Ct,	3404.5	5.5	Pt,	3405.6	5.6	Ct,
	3407.5	5.6	Pt.									
184243 RW LYRAE—												
	3387.5	11.6	B,	3397.5	12.3	Pt.						
184300 NOVA AQUILAE #3—												
	3319.8	10.0	To,	3339.1	9.7	Ch,	3344.7	9.7	To,	3352.7	10.4	To,
	3367.3	10.1	L,	3372.7	10.2	To,	3379.3	9.9	L,	3381.5	9.8	Pt,
	3382.3	10.0	Gi,	3382.7	10.0	To,	3394.5	9.9	Pt,	3401.5	9.8	Pt,
190108 R AQUILAE—												
	3332.4	10.0	Bp,	3342.1	9.8	Ch,	3397.5	11.5	Pt.			
190529a V LYRAE—												
	3398.5	<13.3	Y.									
190907b TY AQUILAE—												
	3397.5	10.9	Pt.									
190926 X LYRAE—												
	3397.5	9.0	Pt.									
190933a RS LYRAE—												
	3345.1	10.0	Ch,	3397.5	11.6	Pt.						
190941 RU LYRAE—												
	3397.5	11.1	Pt.									
190967 U DRACONIS—												
	3340.1	11.9	Ch,	3397.5	9.3	Pt.						
191007 W AQUILAE—												
	3340.1	10.8	Ch,	3397.5	7.8	Pt.						
191017 T SAGITTARII—												
	3342.1	11.6	Ch.									
191033 RY SAGITTARII—												
	3320.7	8.8	To,	3322.7	9.0	To,	3336.1	<10.0	Ch,	3364.2	<9.2	L.
191124 TY SAGITTARII—												
	3338.0	<12.4	Bl.									
191319 S SAGITTARII—												
	3338.0	12.0	Bl,	3349.0	11.8	Bl,	3360.3	11.0	Gi,	3376.2	9.7	Gi.
191331 SW SAGITTARII—												
	3338.0	11.5	Bl,	3349.0	11.8	Bl.						
191350 TZ CYGNI—												
	3322.8	11.0	To,	3345.7	10.3	To,	3352.7	10.3	To,	3372.7	10.2	To,
	3381.5	10.3	Y,	3382.7	10.5	To,	3397.5	10.6	Pt,	3398.5	10.8	Y.
191637 U LYRAE—												
	3397.5	9.0	Pt.									
192928 TY CYGNI—												
	3340.2	10.8	Ch,	3392.5	9.6	M,	3397.5	10.0	Pt.			
193311 RT AQUILAE—												
	3340.2	11.3	Ch,	3397.5	13.9	Pt,	3403.5	13.4	B.			
193449 R CYGNI—												
	3319.8	11.1	To,	3322.8	10.9	To,	3344.7	<12.0	To,	3372.7	<12.1	To,
	3375.5	12.5	Lv,	3397.5	13.0	Pt,	3399.5	<12.1	M.			
193509 RV AQUILAE—												
	3320.7	<12.2	To,	3352.7	<12.2	To,	3372.7	12.2	To,	3397.5	11.6	Pt.
193972 T PAVONIS—												
	3338.0	9.0	Bl,	3349.0	9.2	Bl.						
194048 RT CYGNI—												
	3339.2	9.5	Ch,	3364.3	11.1	Gi,	3380.3	11.9	Gi,	3381.7	9.1	Sg,
	3394.5	9.2	O,	3397.5	11.6	Pt,	3399.5	12.0	M.			
194348 TU CYGNI—												
	3330.4	9.2	Bp.	3375.6	<13.0	Lv.						
194604 X AQUILAE—												
	3397.5	12.5	Pt,	3402.5	11.8	B.						

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
194632 χ CYGNI—												
	3319.1	5.0	Kd,	3321.9	5.0	Kd,	3322.9	5.0	Kd,	3326.0	5.2	Kd,
	3326.2	4.8	Ch,	3332.5	5.1	Bp,	3332.9	5.2	Kd,	3335.9	4.9	Kd,
	3337.9	4.9	Kd,	3339.0	4.9	Kd,	3340.0	5.0	Kd,	3340.9	4.9	Kd,
	3342.9	5.0	Kd,	3344.1	5.0	Kd,	3344.1	5.0	Ch,	3348.0	5.0	Kd,
	3349.0	5.1	Kd,	3349.9	5.2	Kd,	3353.9	5.4	Kd,	3355.9	5.5	Kd,
	3356.1	5.5	Ch,	3359.0	5.6	Kd,	3360.9	5.6	Kd,	3362.0	5.6	Kd,
	3364.2	5.4	An,	3364.9	5.7	Kd,	3366.0	5.7	Kd,	3367.2	5.4	An,
	3369.2	5.5	An,	3369.9	5.7	Kd,	3373.2	5.9	An,	3376.3	5.9	An,
	3376.9	6.1	Kd,	3379.6	4.6	Jb,	3378.6	6.2	B,	3379.2	6.1	An,
	3379.6	6.6	Ct,	3381.9	6.2	Kd,	3382.3	6.3	An,	3382.6	6.7	Ct,
	3385.6	6.6	Ct,	3386.6	6.8	Ct,	3387.6	6.5	B,	3389.6	7.1	Ct,
	3392.5	6.8	M,	3397.5	6.6	Pt,	3398.5	7.8	O,	3400.6	7.0	Ct,
	3403.6	7.2	Ct,	3405.6	7.4	Ct.						
194929 RR SAGITTARII—												
	3338.0	10.9	Bl,	3349.0	10.3	Bl.						
195143 RU SAGITTARII—												
	3338.0	12.7	Bl.									
195202 RR AQUILAE—												
	3327.7	12.2	To,	3347.7	<11.8	To,	3352.7	<12.0	To,	3402.5	<12.5	B.
195308 RS AQUILAE—												
	3301.7	8.9	To,	3320.8	10.1	To,	3345.7	10.8	To,	3352.7	10.8	To.
195653 NOVA CYGNI #3—												
	3342.2	10.7	Ch,	3381.5	10.6	Pt,	3384.3	10.5	Gi,	3387.5	10.8	Pt,
	3390.5	10.9	Pt,	3394.5	10.5	Pt,	3401.5	10.5	Pt,	3404.5	10.8	Pt.
195849 Z CYGNI—												
	3322.8	<12.2	To,	3392.5	12.0	M.	3397.5	12.5	Pt.			
195855 S TELESCOPII—												
	3338.0	13.0	Bl.									
200212 SY AQUILAE—												
	3367.3	12.6	L,	3373.2	13.0	L,	3394.5	<12.1	B,	3397.5	12.2	Pt.
200357 S CYGNI—												
	3375.6	<13.7	Lv,	3403.5	13.9	B.						
200514 R CAPRICORNI—												
	3379.3	11.5	Gi,	3394.5	10.5	B.						
200715a S AQUILAE—												
	3330.4	9.7	Bp,	3350.2	9.4	Ch,	3370.3	9.9	Bp,	3375.3	9.6	Au,
	3381.3	9.9	Au,	3384.3	9.8	Gi,	3385.5	10.5	Ya,	3391.5	9.4	B,
	3392.5	10.7	M,	3397.5	11.8	Pt.						
200715b RW AQUILAE—												
	3385.5	9.1	Ya,	3391.5	9.1	B,	3392.5	8.8	M,	3397.5	8.9	Pt.
200747 R TELESCOPII—												
	3338.0	9.6	Bl,	3349.0	7.9	Bl.						
200812 RU AQUILAE—												
	3383.6	13.3	Lv,	3403.5	<13.0	B.						
200822 W CAPRICORNI—												
	3338.0	<12.8	Bl.									
200906 Z AQUILAE—												
	3376.3	13.6	Gi,	3397.5	11.0	Pt.	3402.5	10.5	B.			
200916 R SAGITTAE—												
	3385.5	9.4	Ya,	3392.5	9.4	M.						
200938 RS CYGNI—												
	3336.2	7.1	Ch,	3355.2	7.2	Ch,	3361.1	8.0	Kd,	3367.3	7.4	L,
	3374.3	8.1	Au,	3377.0	7.8	Kd,	3379.3	7.5	L,	3381.7	7.0	Sg,
	3382.3	8.0	Au,	3382.3	8.0	Au,	3391.6	7.8	Jd,	3397.5	7.3	Pt,
	3400.3	8.3	Au,	3404.7	8.4	Sg.						
201008 R DELPHINI—												
	3367.3	12.5	L,	3370.3	12.5	Bp,	3381.2	12.8	L,	3397.5	13.2	Pt.

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
201121 RT CAPRICORNI—												
	3321.9	7.5	Kd.	3335.9	7.5	Kd.	3337.9	7.5	Kd.	3340.9	7.5	Kd.
	3369.3	6.8	L.	3369.9	7.5	Kd.	3381.2	6.9	L.	3381.9	7.5	Kd.
	3399.5	6.8	Pt.									
201130 SX CYGNI—												
	3381.6<13.3 Y.											
201139 RT SAGITTARII—												
	3338.0	12.4	Bl.	3349.0	11.0	Bl.						
201437b WX CYGNI—												
	3336.2	10.8	Ch.	3374.6	11.6	Lv.	3391.6	10.8	B.	3391.6	11.7	Lv.
	3397.5	11.9	Pt.									
201647 U CYGNI—												
	3330.4	9.9	Bp.	3369.3	11.1	Bp.	3375.2	10.7	Au.	3381.3	10.8	Au.
	3381.4	10.0	Gi.	3392.5	11.3	M.	3397.5	11.8	Pt.	3397.5	9.8	B.
	3401.4	11.1	Au.									
202240 U MICROSCOPII—												
	3338.0<13.0 Bl.											
202539 RW CYGNI—												
	3375.3	8.4	Au.	3381.3	8.7	Au.	3392.5	7.8	M.	3400.2	9.1	Au.
202622 RU CAPRICORNI—												
	3380.2	14.0	Gi.									
202817 Z DELPHINI—												
	3397.5	11.9	Pt.	3402.5	11.4	B.	3406.5	11.3	Lv.			
202946 SZ CYGNI—												
	3383.5	9.8	Pt.	3386.6	9.8	B.	3387.5	9.8	Pt.	3390.5	9.4	Pt.
	3392.5	8.8	M.	3394.5	8.8	Pt.	3400.5	10.0	Pt.	3404.5	9.2	Pt.
	3407.5	8.8	Pt.									
202954 ST CYGNI—												
	3381.5	11.9	Y.	3395.5	11.5	Pt.	3402.5	11.0	Y.			
203226 V VULPECULAE—												
	3392.5	8.6	M.	3398.5	8.8	Pt.						
203429 R MICROSCOPII—												
	3338.0	9.0	Bl.	3349.0	8.8	Bl.						
203816 S DELPHINI—												
	3383.7	8.9	Jb.	3391.5	8.8	B.	3392.5	9.1	M.			
203847 V CYGNI—												
	3336.2	8.2	Ch.	3347.2	8.4	Ch.	3358.2	8.5	Ch.	3374.6	9.0	Lv.
	3381.4	7.9	Gi.	3391.6	9.1	Lv.	3392.5	8.5	M.	3397.5	8.1	B.
	3399.5	8.1	Pt.									
203905 Y AQUARII—												
	3392.5<11.5 M.											
204016 T DELPHINI—												
	3336.2	11.4	Ch.	3381.7	9.0	Sg.	3383.7	9.0	Jb.	3387.5	9.3	B.
	3392.5	9.8	M.	3394.6	9.4	B.	3379.5	9.6	Pt.			
204102 V AQUARII—												
	3343.2	8.4	Ch.	3398.5	9.5	B.						
204104 W AQUARII—												
	3369.2	13.5	L.	3381.2	13.4	L.						
204215 U CAPRICORNI—												
	3343.0	14.0	Bl.	3380.2<14.0 Gi.								
204318 V DELPHINI—												
	3380.3<14.7 Gi.											
204405 T AQUARII—												
	3336.1	9.3	Ch.	3360.1	7.6	Ch.	3369.8	7.6	Jb.	3379.6	7.7	Ct.
	3382.6	7.9	Ct.	3392.5	8.0	M.	3398.5	7.9	B.	3399.5	8.1	Pt.
	3400.6	8.5	Ct.	3403.6	8.6	Ct.	3405.6	8.7	Ct.			
204846 RZ CYGNI—												
	3374.6	14.0	Lv.	3376.4	13.7	Gi.	3391.6	13.5	Lv.	3399.5	14.0	Pt.
204954 S INDI—												
	3343.0	13.3	Bl.	3349.0	13.0	Bl.						

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
205017 X DELPHINI—												
	3374.6	13.3	Lv,	3406.5	<13.3	Lv.						
205017 — DELPHINI—												
	3374.6	12.7	Lv,	3406.5	12.8	Lv.						
205923 R VULPECULAE—												
	3351.2	9.9	Ch,	3364.4	11.0	Gi,	3380.3	11.5	Gi,	3383.6	12.0	Lv,
	3397.6	11.5	B,	3399.5	11.5	Pt.						
210124 V CAPRICORNI—												
	3343.0	11.2	Bl.	3349.0	11.4	Bl,	3360.3	12.0	Gi,	3379.3	12.7	Gi.
210129 TW CYGNI—												
	3381.5	12.0	Y.									
210221 X CAPRICORNI—												
	3343.0	13.5	Bl.	3380.3	<13.6	Gi.						
210504 RS AQUARII—												
	3369.2	<14.0	L,	3381.2	<13.3	L,	3398.5	<13.1	B.			
210516 Z CAPRICORNI—												
	3393.5	<12.5	B.									
210812 R EQUULEI—												
	3402.5	9.7	B.									
210868 T CEPHEI—												
	3336.1	9.9	Ch,	3356.2	10.3	Ch,	3367.3	10.5	L,	3369.3	10.6	Bp,
	3374.3	10.3	Au,	3379.3	10.4	L,	3380.6	10.5	Au,	3383.3	9.8	Au,
	3391.6	9.1	B,	3399.5	9.9	Pt.	3403.3	9.6	Au.			
210903 RR AQUARII—												
	3398.5	<13.3	B.									
211614 X PEGASI—												
	3364.4	9.5	Gi,	3376.4	9.4	Gi,	3389.4	9.6	Gi,	3399.5	10.0	Pt,
	3402.5	10.2	Y,	3402.6	10.2	B.						
211615 T CAPRICORNI—												
	3343.0	9.5	Bl,	3343.1	9.8	Ch,	3349.0	9.7	Bl,	3393.5	11.3	B.
212030 S MICROSCOPII—												
	3343.0	9.9	Bl.									
212814 Y CAPRICORNI—												
	3343.0	12.5	Bl,	3394.5	11.2	B.						
213244 W CYGNI—												
	3319.1	6.5	Kd,	3321.9	6.5	Kd,	3335.9	6.4	Kd,	3340.9	6.5	Kd,
	3342.9	6.5	Kd,	3348.0	6.6	Kd,	3350.0	6.5	Kd,	3355.1	6.5	Kd,
	3359.0	6.5	Kd,	3362.0	6.5	Kd,	3364.2	6.5	An,	3364.9	6.6	Kd,
	3367.3	5.7	L,	3369.9	6.5	Kd,	3373.2	6.5	An,	3377.9	6.5	Kd,
	3378.3	5.9	L,	3381.9	6.4	Kd,	3382.2	6.4	An.			
213678 S CEPHEI—												
	3330.5	8.2	Bp,	3338.2	7.0	Ch,	3375.6	7.7	Lv,	3380.3	8.0	Au,
	3384.5	7.5	Gi,	3385.6	8.2	Ya,	3386.7	8.3	Lv,	3391.6	7.2	B,
	3399.5	7.5	Pt,	3399.6	8.6	M.						
213753 RU CYGNI—												
	3343.2	8.4	Ch,	3399.5	8.0	Pt.						
213843 SS CYGNI—												
	3322.8	12.2	To,	3340.2	9.7	Ch,	3341.1	9.7	Ch,	3342.2	9.7	Ch,
	3343.2	9.4	Ch,	3344.2	9.3	Ch,	3347.2	8.7	Ch,	3348.3	8.5	Ch,
	3349.2	8.5	Ch,	3350.2	8.6	Ch,	3351.2	8.6	Ch,	3352.0	8.6	Kd,
	3352.2	8.7	Ch,	3353.2	8.7	Ch,	3355.2	8.8	Ch,	3356.1	8.8	Ch,
	3358.2	9.2	Ch,	3359.2	9.7	Ch,	3360.2	10.4	Ch,	3360.4	10.6	Gi,
	3361.7	10.9	To,	3361.7	11.2	Lv,	3364.2	11.7	L,	3364.4	11.8	Gi,
	3367.3	11.5	L,	3369.2	11.9	L,	3369.7	12.0	Jb,	3372.7	12.0	To,
	3374.6	11.6	Lv,	3376.4	11.7	Gi,	3377.6	11 8	Wf,	3376.6	11.7	Br,
	3378.3	12.1	L,	3378.6	11.9	B,	3378.7	11.9	Sg,	3379.3	12.2	L,
	3379.6	11.8	Br,	3379.6	<11.8	Jd,	3380.4	11.7	Gi,	3380.6	11.8	Br,
	3380.6	11.5	Y,	3381.2	12.0	L,	3381.4	11.6	Gi,	3381.5	11.6	Pt,
	3381.6	11.6	O,	3381.6	11.5	Y.	3382.4	11.6	Gi,	3382.6	11.7	Br,
	3382.7	11.4	Pt,	3383.4	11.6	Gi,	3383.5	11.6	Pt.	3383.6	11.6	Lv,

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
213843 SS CYGNI—Continued												
	3383.6	11.7	O,	3383.7	11.2	To,	3383.7	11.2	Jb,	3384.4	10.7	Gi,
	3384.7	11.6	Pt,	3385.6	10.5	Br,	3385.7	10.3	Br,	3386.6	10.2	B,
	3387.5	9.3	Pt,	3387.6	9.8	B,	3388.6	9.4	B,	3388.5	9.3	Pt,
	3389.3	9.3	Gi,	3389.6	9.2	Br,	3390.5	8.9	Pt,	3391.6	8.6	O,
	3391.6	8.8	Lv,	3391.6	8.8	Jd,	3391.6	8.7	B,	3392.5	9.0	Pt,
	3392.5	9.0	M,	3392.5	9.0	B,	3393.5	9.3	B,	3393.6	9.2	Lv,
	3394.5	9.2	Pt,	3394.5	9.5	O,	3394.6	9.5	B,	3395.5	9.6	O,
	3395.5	9.8	Y,	3395.5	9.6	Pt,	3396.6	10.3	B,	3397.5	10.9	Pt,
	3397.6	10.7	Lv,	3398.5	11.4	Pt,	3398.5	11.2	O,	3398.5	11.0	Y,
	3398.6	11.2	B,	3399.5	11.7	Pt,	3399.5	11.9	M,	3400.5	11.6	Pt,
	3401.5	11.8	Pt,	3401.6	11.0	Jd,	3402.5	11.4	Y,	3402.5	11.7	O,
	3402.5	<10.9	Ya,	3402.6	11.9	B,	3403.6	11.6	B,	3404.5	11.4	Pt,
	3404.6	11.3	Lv,	3404.6	11.5	B,	3406.7	11.4	Pt,	3407.5	11.4	Pt,
	3408.5	11.6	Y.									
213937 RV CYGNI—												
	3375.3	6.9	Au,	3381.3	8.2	Au,	3387.6	7.6	B,	3399.5	6.5	Pt,
	3399.6	8.2	M,	3400.3	8.6	Au.						
214024 RR PEGASI—												
	3391.6	9.1	B,	3399.5	9.6	Pt,	3399.6	9.3	M,	3402.6	9.5	B.
214247 R GRUIS—												
	3343.0	9.3	Bl.									
215605 Y PEGASI—												
	3383.6	10.5	Lv,	3391.6	10.5	B,	3399.5	11.0	Pt,	3404.6	11.0	B,
	3406.6	11.4	Lv.									
215717 U AQUARII—												
	3399.5	12.2	Pt,	3402.5	11.8	B.						
215934 RT PEGASI—												
	3357.2	<11.7	Ch,	3374.7	11.6	Lv,	3381.6	11.1	Y,	3388.6	10.4	B,
	3391.6	10.8	Lv,	3397.5	10.5	B,	3399.5	10.2	Pt,	3399.6	9.8	M,
	3404.6	10.7	Lv.									
220133b RZ PEGASI—												
	3388.7	7.9	B,	3399.5	8.0	Pt,	3399.6	9.4	M,	3402.6	8.1	B.
220412 T PEGASI—												
	3369.2	13.7	L,	3376.4	<13.7	Gi,	3381.2	14.0	L,	3403.6	<13.9	B.
220613 Y PEGASI—												
	3374.7	12.0	Lv,	3376.4	11.1	Gi,	3379.6	11.0	Br,	3389.4	10.8	Gi,
	3391.6	10.9	Lv,	3398.6	11.2	B,	3406.6	11.2	Lv.			
220714 RS PEGASI—												
	3332.4	11.1	Bp,	3374.7	11.1	Lv,	3376.4	11.6	Gi,	3379.6	12.4	Br,
	3382.3	12.5	Au,	3391.6	12.4	Lv,	3398.6	12.6	B,	3406.6	12.6	Lv.
222129 RV PEGASI—												
	3398.6	12.6	B.									
222439 S LACERTAE—												
	3364.3	10.1	L,	3379.3	9.8	L,	3380.4	9.2	Gi,	3388.7	9.0	B,
	3399.5	8.4	Pt,	3404.6	8.1	B.						
222867 R INDI—												
	3343.0	13.0	Bl.									
223841 R LACERTAE—												
	3380.5	14.6	Gi.									
224354 U LACERTAE—												
	3380.3	8.9	Au,	3382.4	9.0	Au,	3394.3	9.0	Au,	3401.3	9.2	Au.
224455 V LACERTAE—												
	3373.3	9.4	Au,	3403.3	9.5	Au.						
225120 S AQUARII—												
	3398.5	11.2	B.									
225914 RW PEGASI—												
	3380.6	10.1	Br,	3381.6	9.7	Y,	3388.7	9.2	B,	3399.5	9.6	M,
	3402.5	10.3	Y,	3402.6	10.1	B.						

VARIABLE STAR OBSERVATIONS, November 20 to December 20, 1922—Continued.

Star	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.	J.D.	Est.	Obs.
230110 R PEGASI—												
	3322.7	<12.4	To.	3379.6	12.4	Br.	3399.5	12.0	Pt.			
230759 V CASSIOPEIAE—												
	3364.5	8.7	Gi.	3373.2	9.5	Au.	3374.2	9.5	Au.	3375.5	9.3	B.
	3379.3	9.6	Au.	3380.5	9.4	Gi.	3380.6	9.5	Ya.	3381.4	9.9	Au.
	3383.4	10.0	Au.	3384.3	10.2	Au	3384.4	10.0	Au.	3392.6	9.8	B.
	3394.3	10.0	Au.	3399.5	10.6	M.	3399.5	10.9	Pt.	3400.3	11.0	Au.
	3403.4	10.8	Au									
231425 W PEGASI—												
	3364.2	10.8	L.	3374.7	11.0	Lv.	3379.3	10.3	L.	3386.7	9.6	Lv.
	3391.7	9.5	Lv.	3404.6	8.8	Lv.						
231508 S PEGASI—												
	3399.5	12.2	Pt.	3403.6	12.4	B.						
233335 ST ANDROMEDAE—												
	3341.1	9.7	Ch.	3380.5	8.9	Ya.	3385.6	9.0	Br.	3387.6	8.9	B.
	3401.6	8.3	Pt.	3404.6	8.7	B.						
233815 R AQUARII—												
	3322.7	9.4	To.	3336.1	9.3	Ch.	3345.7	9.1	To.	3352.7	9.1	To.
	3369.7	9.3	Jb.	3372.7	9.2	To.	3379.0	9.7	Kd.	3383.7	9.1	To.
	3383.7	9.1	Jb.	3401.6	9.4	Pt.						
235053 RR CASSIOPEIAE—												
	3364.6	11.2	Gi.	3375.5	11.2	B.	3383.4	11.2	Gi.	3391.6	11.2	B.
235209 V CETI—												
	3343.0	<13.6	Bl.	3369.3	13.4	Gi.	3369.3	<13.6	L.			
235350 R CASSIOPEIAE—												
	3364.5	7.9	Gi.	3373.3	7.3	Au.	3375.6	6.9	B.	3380.2	7.1	Au.
	3380.2	7.0	Au.	3381.4	6.9	Gi.	3393.6	6.6	B.	3401.3	7.0	Au.
235525 Z PEGASI—												
	3401.6	11.2	Pt.									
235715 W CETI—												
	3364.3	11.5	Gi.	3376.3	10.3	Gi.	3389.4	9.5	Gi.			
235855 Y CASSIOPEIAE—												
	3380.5	14.1	Gi.	3403.6	13.4	B.						
235939 SV ANDROMEDAE—												
	3381.5	12.7	Y.	3401.6	12.6	Pt.	3402.6	<13.1	Y.			

Total Observations: 1,346. Stars Observed: 347. Observers: 23.

The following observers contributed to this report: Messrs. Ancarani "An" 3, Aurino "Au" 6, Baldwin "Bl", Bemporad "Bp" 6; Bouton "B" 6, Brocchi "Br" 6, Chandra "Ch" 3, Christie "Ct" 2, Ginori "Gi" 9, Hunter "Hu" 8, Jacobsen "Jb" 5, Jordan "Jd" 6, Kanda "Kd" 2, Lacchini "L" 5, Leavenworth "Lv" 10, McAteer "M" 5, Olcott "O" 5, Peltier "Pt" 6, Skaggs "Sg" 5, Townley "To" 5, Waterfield "Wf" 12r, Yalden "Ya" 4, and Miss Young "Y" 8.

HOWARD O. EATON, *Recording Secretary.*

Period of V Hydrae.—In all recent variable star catalogues, the very red star, V Hydrae, *104630*, has been classed as irregular. In 1888 Chandler assigned a period of 575 days, and mentioned large irregularities. In his third catalogue the period is withdrawn.

A discussion by Mr. Campbell of 12 maxima and minima, observed visually since 1905, indicates a period of 530 days, with an average deviation of ±16.6 days. The mean light curve shows evidence of a secondary minimum.

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COMET NOTES.

Comet c 1922 (Baade).—As shown by the accompanying diagram, Baade's comet is receding from the earth and coming down to the plane of the

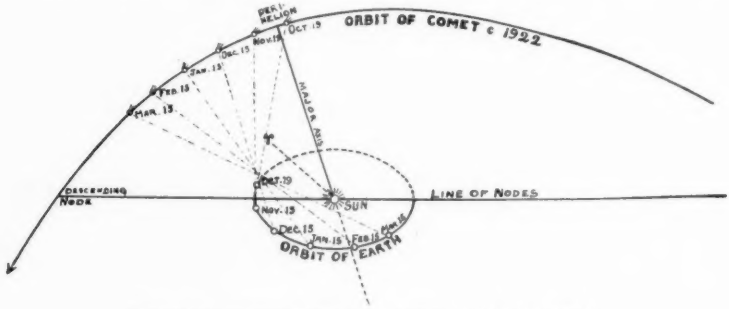

DIAGRAM OF THE ORBIT OF COMET *c* 1922 (BAADE).

ecliptic, so that its position is rapidly becoming unfavorable for observation. The diagram was prepared by means of the elements by Hamilton M. Jeffers, published in the December, 1922, number of POPULAR ASTRONOMY.

Skjellerup's Comet.—A letter received from Director Gallo of the Mexican National Observatory, at Tacubaya, gives the following elements for Skjellerup's Comet, (d) 1922, computed by Professor Chacón from observations of November 25, December 7, and December 18.

ELEMENTS.

Time of perihelion passage	(T)	1923, January 3.4938 G. M. T.
Perihelion minus node	(ω)	264° 12′ 14″
Longitude of node	(Ω)	261° 55′ 31″
Inclination	(i)	23° 21′ 29″
Perihelion distance	(q)	0.9248

The December observations were made at Tacubaya. The representation, O — C, on December 7 was $\Delta\alpha = -2^s$, $\Delta\delta = -11''$.

The following position of Skjellerup's Comet has been received here:

G. M. T.	R. A. (h m s)	Dec. (° ′ ″)	Observer	Place
December 2.9431	11 34 59.2	—17 00 28	Van Biesbroeck	Yerkes

The comet was of the eighth magnitude on December 2.

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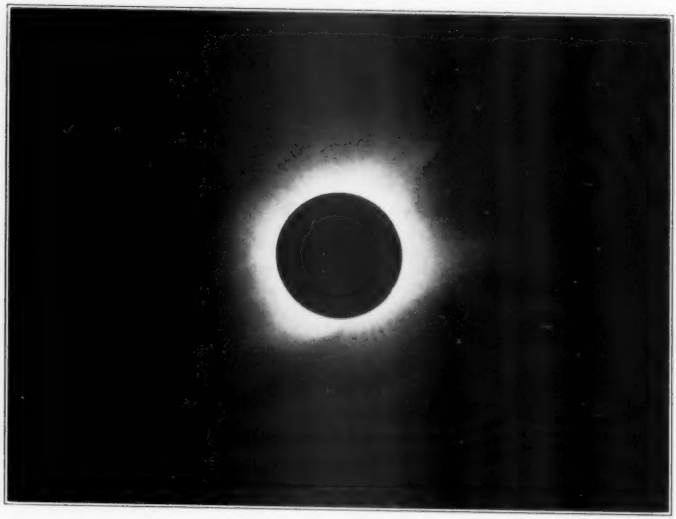
GENERAL NOTES.

Dr. Fritz Cohn, professor in the Berlin University, and for many years director of the Astronomischen Rechen-Institut at Berlin, died on December 14, 1922, after a short illness.

PLATE VIII.



THE TOTAL SOLAR ECLIPSE OF SEPTEMBER 21, 1922.

From a photograph taken at Wallal, Australia, with the Floyd Camera, aperture 5 inches, of the Crocker Eclipse Expedition from the Lick Observatory.

Mr. Paul Bruck, director and astronomer of the Observatory of Besançon, France, 1884-1922, died on July 31, 1922.

Professor W. W. Campbell has recently been elected to the presidency of the University of California, one of the largest universities in the United States. Astronomers will be pleased to know that Professor Campbell, in accepting this high and arduous position, is not to sever his connection with the Lick Observatory. In reply to our letter of inquiry he replies: "It was not possible for me to accept the Presidency of the University of California, if this meant the cutting of the ties which have been binding me here more and more closely through thirty-two years. The Regents said this would not be necessary: that I could retain the Directorship in so far as general policies were concerned, and that an Associate Director could be charged with all detailed administrative duties. Mrs. Campbell and I retain our residence here, and to it we shall hope to return many times each year, especially in the Christmas and summer-vacation periods.

"An additional and compelling reason for the condition outlined above is that I last year assumed very serious obligations with well-known astronomical organizations."

Pickering Astronomical Fellowship for Women.—Two Pickering Astronomical Fellowships for Women are now open at the Harvard College Observatory. The work of the Fellows involves, in general, research problems based on Harvard stellar photographs. The annual stipend is $650. Arrangements can be made for the holder of a fellowship to receive credit toward a higher degree in Radcliffe College.

HARLOW SHAPLEY.

Photograph of the Total Solar Eclipse of September 21, 1922. —The beautiful photograph of the solar corona reproduced in Plate VIII was sent to the editor with Christmas greetings from Professor and Mrs. Campbell. The photograph was taken with the 5-inch Floyd camera used by the Crocker Eclipse Expedition from the Lick Observatory, at Wallal, Australia. The reproduction is on the scale of the original photograph. The type of coronal streamers appears to be that which is usual at the times of sunspot minima, the long streamers running east and west parallel to the sun's equator.

English Translation of Newcomb-Engelmann's "Populaere Astronomy". — Professor Henry Meier, of Centre College, Danville, Ky., writes that Wilhelm Engelmann, the publisher, has arranged with him to translate into English the seventh edition, the revision of which has just been finished, of the Newcomb-Engelmann "Populaere Astronomie." Mr. Meier has the translation well under way.

New Spectrum of Class O.—On a photograph made at Arequipa in April, 1922, Miss Cannon finds the star C.DM. —45°4482, mag. 10, to have a spectrum of Class O. The band 4686 is the strongest portion of the spectrum. The position for 1900 is $8^h\ 41^m.4$, —45° 37′.

Harvard College Observatory Bulletin 781.

Resumé of Sun Spot Observations at Mount Holyoke College, 1922.

Month	No. of Obs.	North of Equator No. of Groups	Av. Lat.	South of Equator No. of Groups	Av. Lat.	Av. No. at one Obs.	New Groups
January	18	3	+13°5	3	—6°0	1.11	6
February	14	2	14.8	3	1.9	1.36	5
March	15	7	11.7	4	9.5	2.27	9
April	15	6	9.4	0	...	1.13	4
May	20	3	8.5	0	...	0.45	2
June	10	3	9.2	0	...	0.90	2
September	9	1	5	2	10.0	0.67	3
October	21	2	14.0	3	9.3	0.57	4
November	17	1	6.5	3	5.4	0.76	3
December	13	0	...	2	2.2	0.85	1
Total	152	28		20			39

Average number at one observation	0.99
Average latitude of groups north of equator	+10.7
Average latitude of groups south of equator	— 6.5
Number of days without spots	56

John Payson Williston Observatory. ALICE H. FARNSWORTH.

The Origin of Spectra by Foote and Mohler of the U. S. Bureau of Standards, American Chemical Society Monograph Series.

This book of 250 pages brings together a great amount of valuable material on the subject and presents it in connected form. Those who work in the spectroscopic field, as well as those desiring a knowledge of the subject as it is today, will find this monograph of special interest. Chapter titles are as follows: 1. The Quantum Theory of Spectroscopy; 2. Energy Diagrams; 3. Ionization and Resonance Potentials for the Elements; 4. Line Absorption Spectra of Atoms; 5. Line Emission Spectra of Atoms; 6. Cumulative Ionization; 7. Thermal Excitation; 8. Thermochemical Relations; 9. X-Ray Spectra; 10. Photo-Electric Effect in Vapors; 11. Determinations of h (Planck's constant) involving Line Spectra. In an appendix are collected a variety of computational data and an exposition of Bohr's theory of atomic structure. The many references to original papers and books will be especially valuable to anyone who wishes to examine sources. The American Chemical Society is doing a great service to all scientific workers in publishing this and other monographs on modern scientific subjects.

The Distances of the Globular Clusters.—Under this heading a note was published in POPULAR ASTRONOMY for June-July, 1922, in which reference was made to a paper by Kapteyn and van Rhijn on the distances of the globular clusters as inferred from the Cepheid variables and that the results obtained by them amounted to only about 15 per cent of those derived by Shapley from his Mt. Wilson observations. In Harvard College Observatory Circular 237, Shapley draws attention to the great probability that the proper motions of the stars used by Kapteyn and van Rhijn are exceptional, because of their high space velocities, and that therefore the usual formulae connecting distance and proper motion are not applicable to these stars. The Circular is too long for reproduction here and cannot be condensed without too much loss. Those interested

in the problem of the dimensions of the stellar system are therefore referred to the Circular itself.

At the December, 1922, meeting of the American Astronomical Society a paper was presented by Dr. Ralph E. Wilson, giving a preliminary discussion of the proper motions of some sixty Cepheid variable stars. One result which appeared to come from this discussion was that Shapley's parallaxes for the Cepheids should be multiplied by about 1.7, or perhaps by a factor as small as 1.5 or less.

Period of W Tauri.—In the various published catalogues no period has been assigned to the variable star W Tauri, 042215. It is listed as irregular. Since 1904, the star has been regularly observed here and by members of the variable star associations, and since 1917 a period of about 266 days has been recognized in the lists of predicted dates of maxima published in Harvard Circulars.

From a discussion of 24 maxima and 23 minima, observed since 1904, it is found that the elements, J. D. $2416660 + 266^{d}.5 \cdot E$, satisfy the data with a fair degree of accordance. A discussion of fourteen published maxima and three published minima, for the years 1887 to 1900, indicates the following elements for that interval: J. D. $2410350 + 275^{d} \cdot E$; three other published maxima and one minimum were rejected. The evidence for a large change in the period appears conclusive. The light curve shows a slightly wider maximum than minimum, but is not abnormal for its class.

Harvard College Observatory Bulletin 781.

Five New Variable Stars.—The following new variable stars have been found recently on Harvard photographs.

Harvard Variable	R. A. 1900 h m	Dec. 1900 ° ′	Maximum	Minimum	Discovered by
3635	18 13.7	−32 15	11	15	Miss Cannon
3636	+1200″	−1970″	13	⟦16.5	Bailey
3637	22 17.4	+21 39	13.8	⟦15.2	Miss Woods
3638	22 38.9	+ 1 13	12.0	15.3	Miss Woods
3639	23 52.4	+31 29	12.0	⟦15.2	Miss Woods

No. 3635 was found from the spectrum, which is of Class Mb with Hγ and Hδ nearly equally bright. The variable was bright in July, 1893, June 1913, and July, 1922. Apparently the period is long.

No. 3636, which appears to be a long period variable, is 39′ from the center of the globular cluster N. G. C. 6656. The tabulated positions for this star are the rectangular coördinates from the center of the cluster.

The symbols ⟧ and ⟦ will be used to indicate "brighter than" and "fainter than," respectively, instead of the symbols $>$ and $<$, which have been used ambiguously heretofore in giving the brighter and fainter limits of magnitude for variable stars.

Harvard College Observatory Bulletin 781.

Nova Aquilae 1918.4.—Photographic and visual observations made at Harvard on Nova Aquilae 1918.4 (No. 3) give the magnitudes at present as 10.2 and 10.1, respectively. The nova has decreased more than eleven magnitudes since June, 1918, and is now but little brighter than before the outburst.

The spectrum of the nova on a photograph taken by Miss Cannon at Arequipa on August 21, 1922, shows four bright bands at or near 5007, 4640, Hγ, and Hδ. There is only slight contrast between the bright bands and the continuous spectrum, and the chief nebular lines are not brighter than the band at 4640.

A photographic light curve, based on more than a thousand plates, is now being published as No. 7 of Harvard Annals **81**. A comparison of the Harvard visual and photographic curves shows that the color index throughout the whole recorded history of the star has remained within the limits +0.2 and —0.5, except for a few sporadic and uncertain observations.

Harvard College Observatory Bulletin 781.

OCCULTATION OF VENUS JANUARY 13, 1923.

At Northfield the sky was overcast and, although students of two classes in astronomy assembled to witness a rare phenomenon, nothing could be seen of the occultation of Venus on the morning of January 13.

Professor Rigge writes that the sky was perfectly clear at Omaha, Nebraska, and that the phenomena of the occultation occurred exactly at the predicted times.

The following reports have been received from other observers who were fortunate in having clear skies. The photographs secured by Professor Slocum at the Van Vleck Observatory, Middletown, Conn., and by Mr. William Henry of Brooklyn, N. Y., are very good and will be much appreciated by our readers (see Plates VII and IX. See also p. 122 for report by Professor Slocum).

In the early morning of January 13, dwellers in the eastern and middle sections of the United States had the opportunity of witnessing a rare astronomical event, an occultation of the planet Venus by the moon. An occultation of

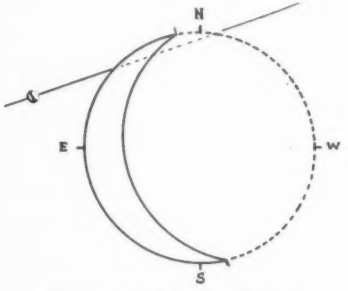


DIAGRAM OF OCCULTATION OF VENUS, JAN. 13, 1923.

Venus by the moon is not such a rare phenomenon for the earth as a whole, but for any one place is extremely rare. For instance, there has not been one visible here since early in December, 1877, forty-five years ago.

The accompanying diagram shows the appearance of the event as observed by the writer through a small telescope. January 12 was a dark and cloudy day and continued as such up until about 10:30 P. M., when the clouds began to

PLATE IX.

5:45 A. M. 6:05 A. M. 6:30 A. M. 6:45-7:25 A. M. 7:26 A. M.

THE OCCULTATION OF VENUS BY THE MOON, JANUARY 13, 1923.
Photographs by William Henry, Brooklyn, N. Y.

disperse, and by 3:30 A. M. on the 13th the sky was clear. The temperature was very low and the stars seemed to sparkle with an intensity almost electric. By 5:30 A. M. it was apparent to even the most inexperienced observer that the moon would pass directly over Venus. Nearer and nearer came the two objects, the moon a slender crescent, —3.5 days old, while Venus was two weeks past maximum brilliancy and of about —4.3 magnitude, or nearly 133 times as bright as α Tauri.

First contact occurred at $6^h\ 56^m\ 53^s$ and the planet disappeared behind the bright limb of the moon at $6^h\ 59^m\ 55^s$. Reappearance occurred at $7^h\ 19^m\ 51^s$ and last contact at $7^h\ 21^m\ 48^s$. The phase of the moon is shown in the diagram, and the north cusp is 8° 16′ east of the north point. Immersion occurred at approximately N 28° E. and emersion at nearly N 2° W. These values are estimated only, as no equatorial mounting was used on the telescope. Seeing was not good, a slight haze being present during the first part of the occultation and daylight interfering to some extent during the latter part. All times given are E. S. T.

LEWIS J. BOSS.

North Scituate, R. I., January 13, 1923.

We were fortunate here in having clearing skies just in time to observe the occultation of Venus on the morning of January 13. The seeing was very poor, the images being extremely unsteady, which made all the observations uncertain by possibly two or three seconds. It was especially difficult to get the first contact on account of the dancing of the image of Venus.

The results of the observations follow:

		h	m	s			
Contact	1	6	41	46	A. M.	Civil.	Position Angle 40°
"	2	6	44	56	"	"	Position Angle 36°
"	3	7	17	58	"	"	} P. A. of estimated center of
"	4	7	20	58	"	"	} Venus when emerging 338°

Positions of contacts 1 and 2 were obtained by noting points of contact with reference to lunar features, then, after plotting on a chart of the moon, the position angles were measured with a protractor. As there were very definite lunar features near the points of contact the positions for contacts 1 and 2 should be correct within 2 or 3 degrees. The position of the last contact for center of Venus was estimated with reference to the N cusp of the crescent moon and prominent lunar features, plotted accordingly on chart and scaled with a protractor.

I do not know whether these results will be worth much but they are the best I could get under the circumstances. I think the times of all contacts, except the first, are accurate within two or three seconds or possibly closer. The first may be off as much as ten seconds. The position of our observatory is Lat. 42° 27′ 12″ N. Long. $5^h\ 05^m\ 54^s.3$ W.

SAMUEL L. BOOTHROYD.

Fuertes Observatory, Cornell University,
Ithaca, N. Y., January 16, 1923.

The occultation of Venus as observed at South Hadley, Mass., on the morning of January 13 was a spectacle of rare beauty. As we were not far from the northern limit of visibility for the occultation only the extreme northern part

of the moon covered the planet, which was completely concealed for only nineteen minutes.

Until within a few seconds of its disappearance Venus could be seen with the naked eye, looking like a star resting on the tip of the crescent moon. The planet was much brighter than the moon's disk and looked as if it were in *front* of the moon rather than millions of miles beyond it.

Dr. Alice Farnsworth observed the sidereal time of contacts with the eight-inch telescope. For convenience the corresponding eastern standard time is also given. The time of the first contact may be in error by several seconds, while that of the last was uncertain by perhaps twenty seconds. I noted contacts with a 2½-inch portable telescope, using a standard time chronometer, but the observation of first contact was very uncertain and the images were too unsteady to make a record of last contact possible. These times are given in the last column.

	8-inch Sidereal Time	8-inch E. S. T.	2½-inch E. S. T.
	h m s	h m s	h m s
Immersion	14 30 46	6 53 20	
	35 44	58 17	6 58 17
Emersion	14 54 48	7 17 18	7 17 23
	58 30	20 59	

ANNE S. YOUNG.

Mount Holyoke College, January 16, 1923.

The occultation of Venus, January 13, was observed at the Student Observatory of Swarthmore College. Unexpectedly good weather conditions prevailed at Swarthmore, which was very lucky, considering that it snowed the night before. The immersion was observed through a rather large opening in some drifting clouds which covered the sky at the time. The seeing was very good, the only boiling, of the cusps of Venus, being slight. The emersion was seen under a perfectly clear sky, but the seeing unsteady under a rising NW wind. The occultation itself was observed by R. C. Spencer and Earl Williams at the 5-inch guiding telescope of the 9-inch photographic doublet, and by Walt Keighton and myself at the 6-inch equatorial, which is about fifty feet east of the former observatory.

The times given are the mean of the two observations, which were reduced to the center of Venus by the members of the former party. As may be seen they agree very closely with the times predicted by L. J. Comrie, of the observatory staff.

		h m s	
Immersion	Computed	6 38	E. S. T.
	Observed	6 37 45	
Emersion	Computed	7 26	E. S. T.
	Observed	7 25 45	

For the position of Swarthmore, which is Longitude $5^h\ 1^m\ 24^s$ West of Greenwich and Latitude $+39°\ 54'\ 23''$, the emersion occurred exactly at the vertex. The difference between first and last contact was about one minute for both immersion and emersion. The immersion was the most beautiful astronomical phenomenon that I have ever seen, and I, for one, will be impatiently waiting for the next occultation of a planet.

RICHARD BARRINGER.

2105 Walnut St., Philadelphia, Pa.
January 17, 1923.

I enclose a copy of some photographs which I made of the occultation of Venus on January 13.

The morning of the 13th was very clear here in Brooklyn, and the sight was gorgeous.

Besides making the photos I also observed with my 5-inch Clark telescope. While observing the contact of Venus with the moon I was rather puzzled to see the images outlined quite distinctly against the yellow disk of the moon, which gave the impression that it was going to pass in front, instead of behind, the moon. This persisted until one of the cusps was sharply cut off, after which the image grew smaller and then disappeared. One of my friends here also noticed the same effect with his telescope. Possibly this was caused by the atmosphere of Venus.

WILLIAM HENRY.

547 East 4th Street, Brooklyn, N. Y., January 17, 1923.

The following observations were made of the occultation of Venus, Jan. 13, at the Flower Observatory, by S. G. Barton with the 18-inch and by Dr. J. D. Maddrill with the 4¼-inch portable telescope. The times are local mean times of contact of first cusp, disappearance, reappearance of first cusp and last contact in order:

	h m s	h m s	h m s	h m s
Barton	6 35 58.5	6 38 26.6	7 23 59.6	7 26 4.2 A. M.
Maddrill	6 35 46	6 38 26	7 24 50	7 26 35

S. G. BARTON.

University of Pennsylvania, Philadelphia,
January 17, 1923.

Relief of Russian Astronomers. — The following letter, sent out by the Committee for the Relief of Russian Astronomers, gives an account of what has been done up to date and indicates that there is still need of further assistance.

THE UNIVERSITY OF CHICAGO, YERKES OBSERVATORY

Williams Bay, Wis., January 25, 1923.

Dear Sir:—The measures taken by the American astronomers through this Committee for the relief of their Russian colleagues during the year 1922, may be regarded as successful.

Up to date there has been sent to the Committee $2039.85. The expenditures have been $1937.18. Of the balance, $45 is reserved to be sent in installments to individuals, as specifically designated by the donors. This leaves us with a balance of $57.67 available to respond to calls for assistance.

Out of about 180 food packages there are only two (of those for which there has been time for reply to be received) for which we have received no notice of delivery by the A. R. A. or acknowledgment from the recipient. We regard this as a remarkable tribute to the efficiency of the American Relief Administration.

Our last regular monthly distribution to individuals at about fifteen institutions, was made in August. In view of their new harvest it seemed wise to wait for direct information as to the need of continuing the monthly food packages. The food situation is much better in certain regions. One of our colleagues at

Pulkowa says that he has grown so much stouter that he has had to have the buttons on his coat moved. Conditions are now the worst in the Crimea. We have sent $20 in cash to Stratonoff, who was recently arrested and exiled, and the same to Wissotsky, who was a refugee at Bizerta, Tunis. These exiles deserve special sympathy and support. A certain part of the fund was placed in our hands with the understanding that it could be used for any form of Russian Relief other than food, that seemed wise to the Committee. We have thus sent $30 for a supply of about 35 dozen photographic plates to the Pulkowa Observatory from Germany, through the kind assistance of Professor Max Wolf, and we have purchased, at a generous discount, volumes of the Astronomical Journal, Popular Astronomy, and the Astrophysical Journal, to complete the files for the years of the War and after, for the libraries at Pulkowa and at Moscow University Observatory. The Ceraskis were finally reached, and they received all our food packages. We sent them also a standard A. R. A. $20 clothing package. The daughters of Simon Newcomb are now privately providing for the Ceraskis for the rest of this winter.

At our suggestion, the Carnegie Institution of Washington has very generously sent a set of their astronomical publications to twelve Russian observatories and universities on our list—a gift which will be greatly appreciated by the Russians, who sometimes say that they feel even more moral support from gifts of scientific literature than from food.

Under the circumstances, we feel that at least $300 more should be provided to cover special cases of distress in the worst parts of Russia and for the stranded exiles. May we, therefore, ask if the members of the staff of your observatory would be disposed to make two monthly contributions similar to those sent to us last year, if this is agreeable to the contributors. Food packages sent in the next fortnight will begin to reach our Russian friends at about the end of winter, when food supplies will be scanty.

The expressions of appreciation received from Russia have been very warm, and almost embarrassing. For this reason they can hardly be printed.

Checks may be made, as heretofore, to the order of the Chairman of this Committee.

With many thanks for your cordial co-operation in this undertaking,

Very truly yours,

THE COMMITTEE FOR THE RELIEF OF
RUSSIAN ASTRONOMERS.
EDWIN B. FROST, *Chairman.*
G. VAN BIESBROECK.
OTTO STRUVE.

A Correction. — Mr. M. Stahl requests us to say that the poem on page 637 of the December number of POPULAR ASTRONOMY was not written by him but was merely contributed by him. The attachment of his signature to the verses was an error on our part.

Erratum.— On page 91, at end of third line from bottom insert the word Paris.